TOXIC EMISSIONS AND AIR QUALITY IN THE LAKE HURON - LAKE ERIE CORRIDOR

DECEMBER 1990

Ontario
Environment
Environnement

ISBN 0-7729-7588-4

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Huron Erie Corridor Committee (HECC)
Air Resources Branch
Ministry of the Environment

DECEMBER 1990

Cette publication technique
n'est disponible qu'en anglais

PIBS 1320
log 90-2203-122

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1 INTRODUCTION

This report consists of a preliminary analysis of atmospheric emissions, air quality and soil and vegetation contamination in the Ontario Michigan border area in southwestern Ontario. This area extends from the southern end of Lake Huron, along the St. Clair River, through Lake St. Clair, and along the Detroit River to Lake Erie. This area will be referred to as the Huron Erie Corridor or simply the Corridor. This analysis is intended to evaluate the conditions on the Ontario side of the Corridor and draws on information from other areas to permit comparisons. The analysis must be considered as preliminary in nature due to the sparsity of relevant and available data, and the limited time available for completing such an analysis.

The purpose of this analysis was:

1. to assemble the available air and other relevant data for the Corridor and for other comparable or contrasting areas; and

2. to evaluate the data by comparing it with similar data from other areas, and by conducting pertinent meteorological analyses to delineate contributing pollution source areas.

The analysis focuses on a few selected compounds out of the several hundred air pollutants known to be emitted in the Corridor. These are generally monitored by agencies in the Corridor and are of concern from a health perspective.

Section 2 reviews information on emission sources of organic contaminants and some inorganic contaminants. Emission estimates for the Corridor are compared to other areas in Ontario as well as eastern North America.

Section 3 attempts to place the concentrations of organic contaminants in ambient air at Corridor locations in perspective with similar measurements made elsewhere. This section also applies some meteorological analyses to diurnal patterns of reduced sulphur concentrations to identify probably sources of these compounds. Similar analyses for organic contaminants are also undertaken but are restricted by a lack of hourly measurements.

Section 4 examines ambient air concentration data for such contaminants as SO_2, TSP and trace metals and compares these among major Ontario cities. The mean concentrations of these pollutants are ranked and compared to the size ranking of the city, based on population.

Section 5 analyzes available data for soil and vegetation concentrations of metals and other inorganic contaminants as determined for Windsor areas, and compares these to similar data collected in Metropolitan Toronto.

2 EMISSION INVENTORY FOR SELECTED ORGANIC AND INORGANIC CONTAMINANTS

Emission estimates for PAH (30 compounds), PCDD and PCDF were obtained from a draft report prepared by ORTECH International (1990). Other contaminant emission estimates came from internal (MOE, ARB) sources. All estimates are based on 1985 information.

2.1 Polycyclic Aromatic Hydrocarbons (PAH)

In Ontario the predominant source of PAH emissions is the combustion of wood for residential heating (wood stoves and fireplaces). Such sources were estimated to account for approximately 70% of the Ontario PAH emissions. On a larger scale, wood combustion accounts for approximately 31% of PAH emissions in eastern North America.

Figures 1a and 1b represent the spatial distribution and intensity of PAH emissions in eastern North America and Ontario. Major individual point sources of PAH include primary aluminum smelting and production facilities and steel mills. The former do not occur in Ontario. It can be observed from Figure 1a that on the continental scale, southwestern Ontario, which includes the Huron Erie Corridor, is not an area of high PAH emission density. However, on a smaller scale, major population centres in Ontario are distinguished as area sources of PAH (Figure 1b).

2.2 Polychlorinated Dibenzo Dioxin (PCDD) and Polychlorinated Dibenzo Furans (PCDF)

Municipal waste incineration and residential wood combustion were found to be the major sources of PCDD and PCDF emissions in eastern North America, as well as in Ontario. Figures 2a, 2b, 3a and 3b indicate that the largest emission densities of PCDD and PCDF are associated with populated areas due to the concentration of the combustion related sources. An area centred on Detroit, Michigan is considered a major source area of PCDD and PCDF emissions. On the continental scale, southwestern Ontario is not distinguished as a major source area of PCDD and PCDF emissions.

2.3 Benzene

Benzene emissions in Ontario are concentrated in large urban and industrial areas such as the Toronto to Hamilton corridor, Ottawa, Sarnia, and Windsor (Figure 4). High emission levels are also observed along major vehicular arteries such as the 401 and Queen Elizabeth Way highways.

2.4 Dichloromethane

Dichloromethane emissions are mostly from point sources such as dry cleaning and surface coating facilities. As a result, high emission source areas include large urban centres such as Toronto, Hamilton, Ottawa, London, Windsor and Sarnia (Figure 5).

2.5 Cadmium and Arsenic

Cadmium and arsenic emissions are primarily a result of base metal smelting and refining activities (EAG, 1988). The areas with the highest emission densities of cadmium and arsenic are centred primarily on Hamilton and northern Ontario towns and cities containing such industries (Figure 6 and 7).

FIGURE 1a

Annual Emissions of PAH (Point and Area)
in Eastern North America

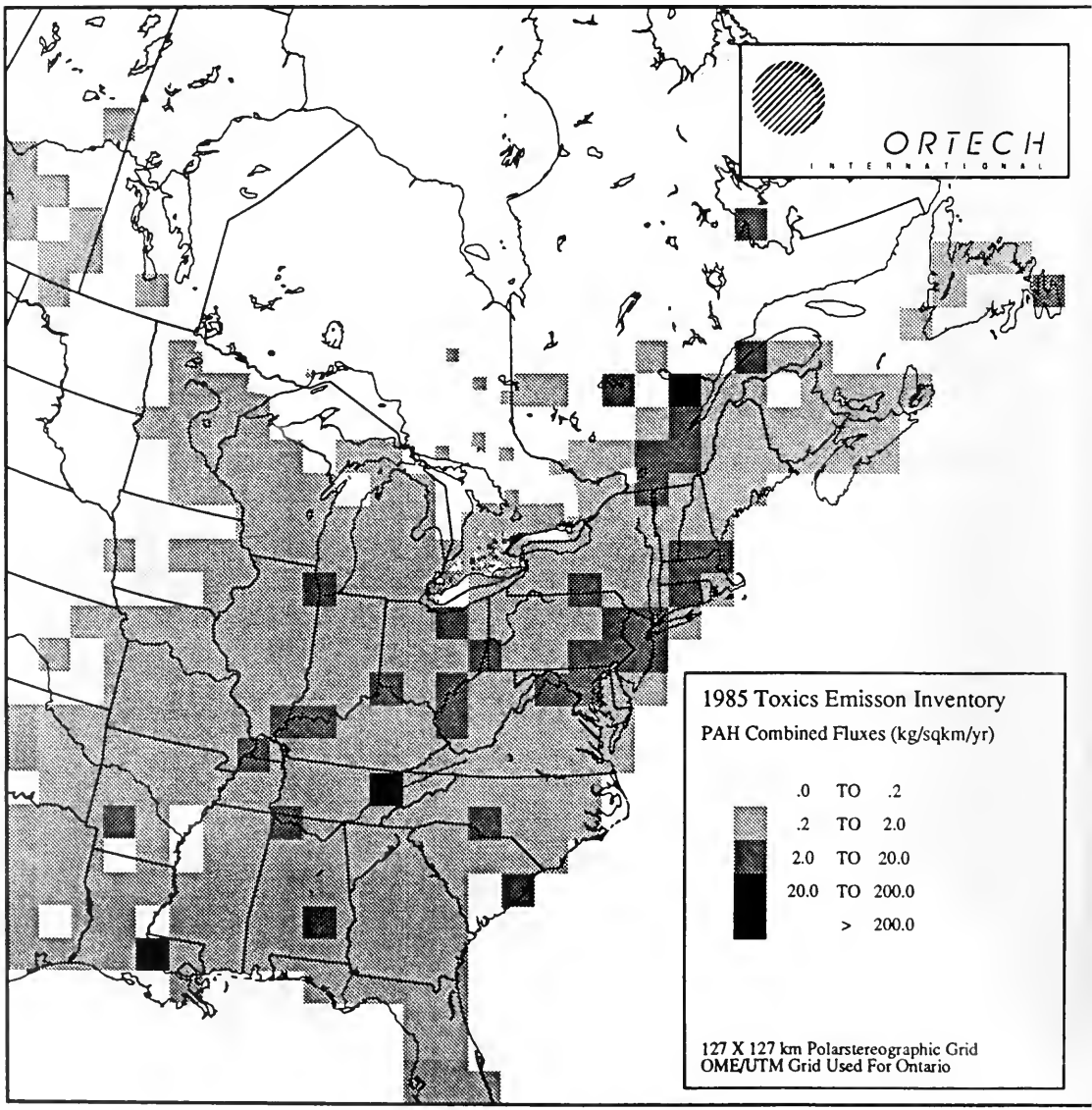


FIGURE 1b

Annual Emissions of PAH (Point and Area)
in Ontario

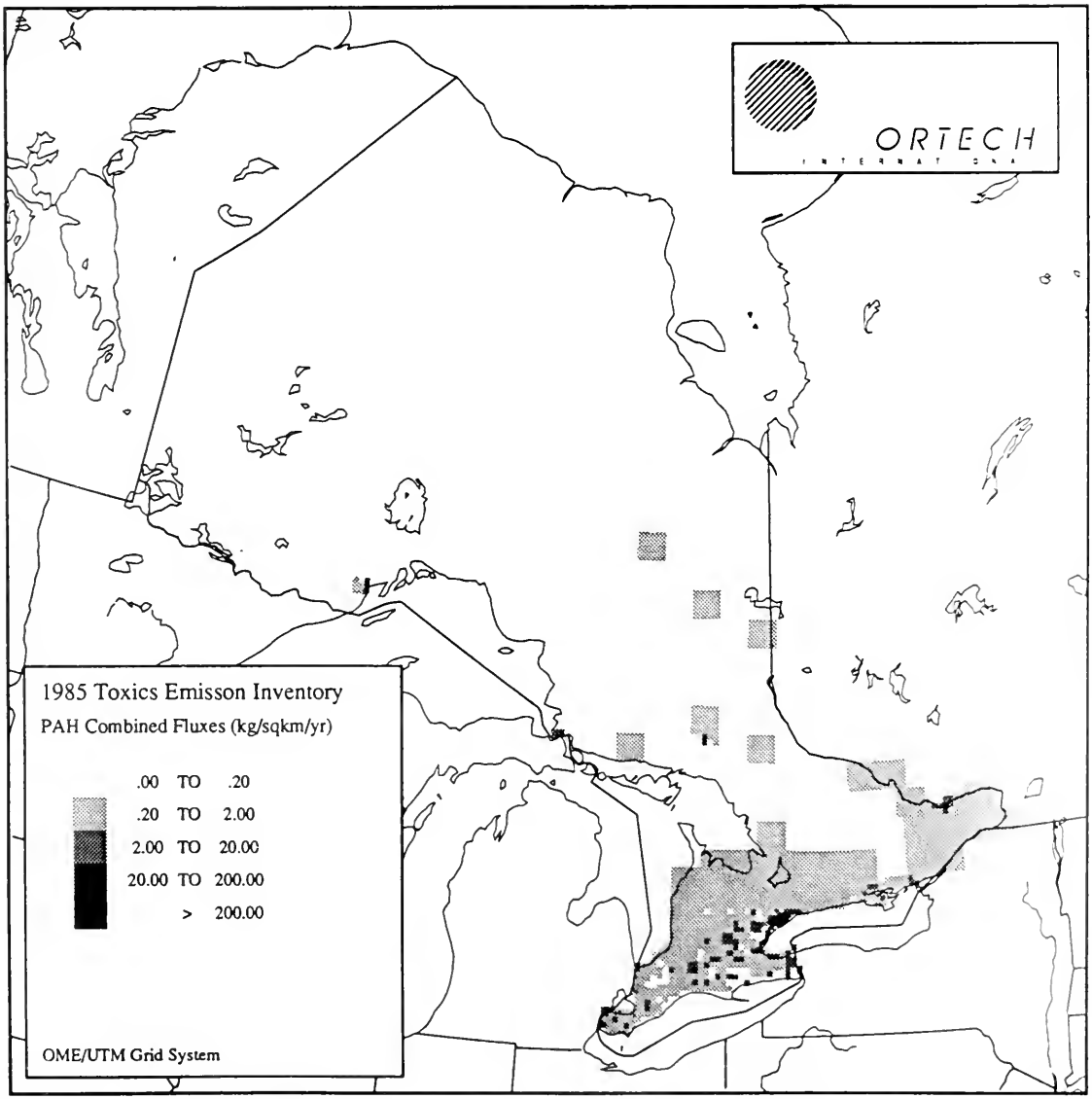


FIGURE 2a

Annual Emissions of PCDD (Point and Area)
in Eastern North America

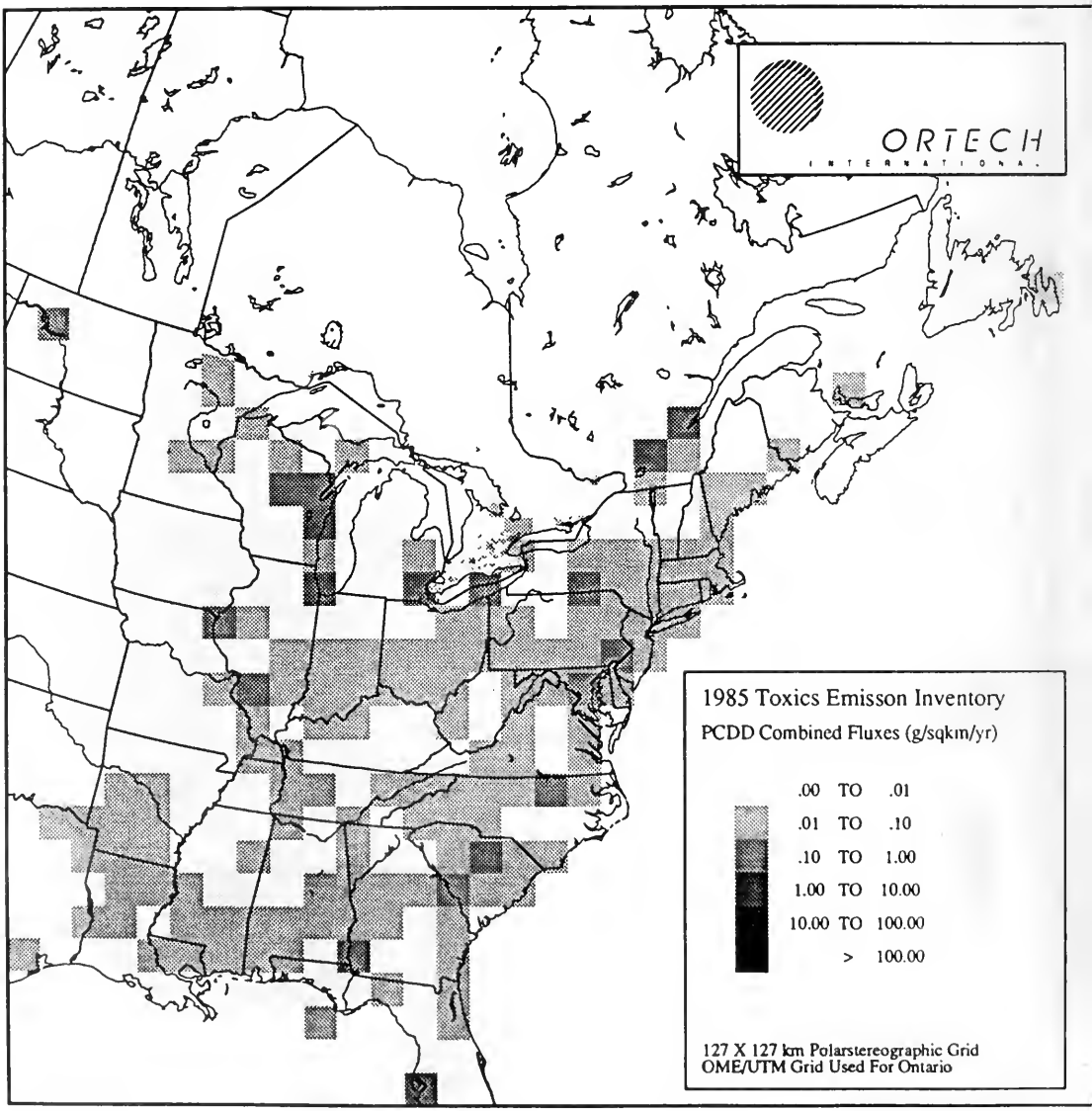


FIGURE 2b

Annual Emissions of PCDD (Point and Area)
in Ontario

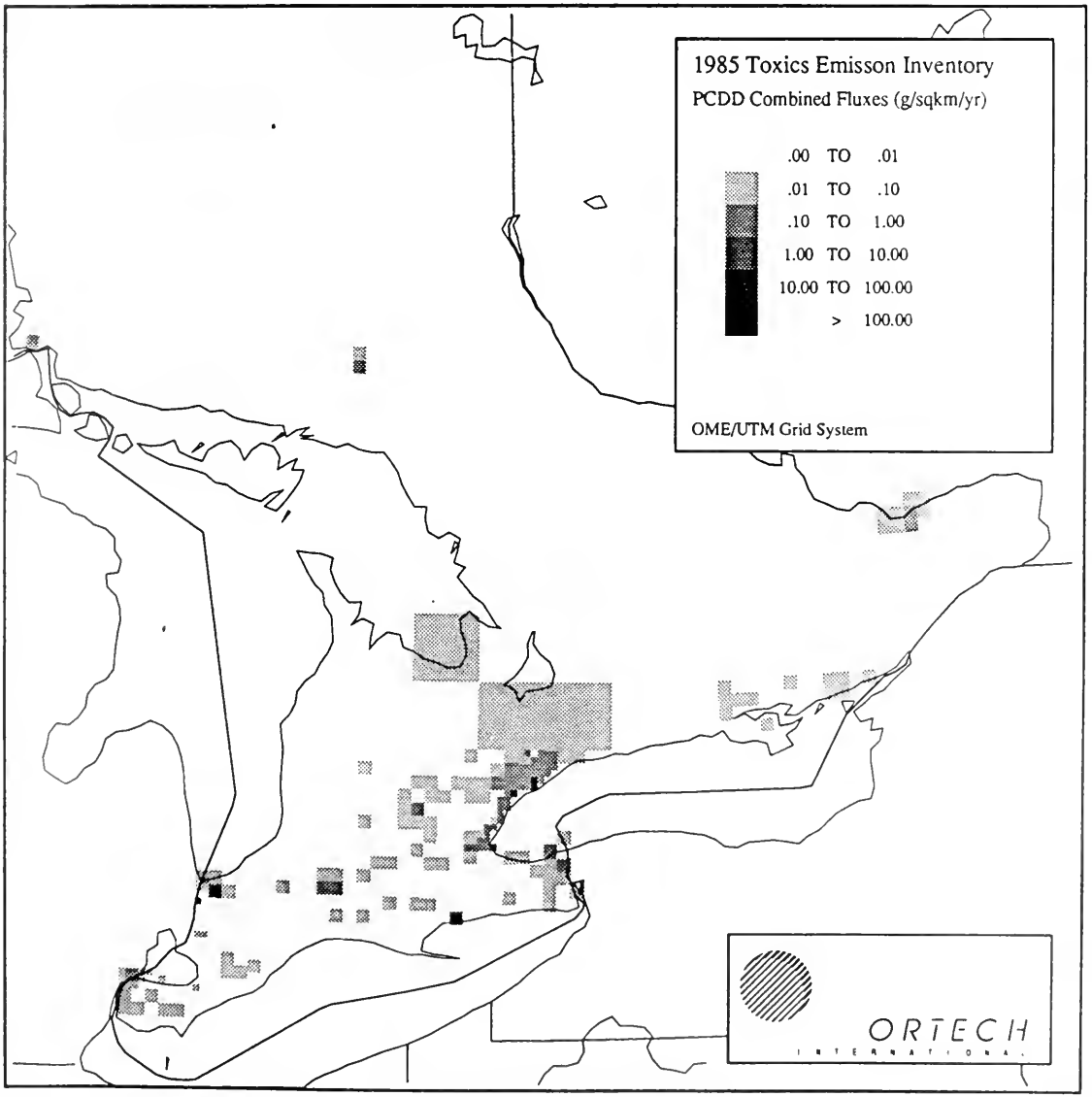


FIGURE 3a

Annual Emissions of PCDF (Point and Area)
in Eastern North America

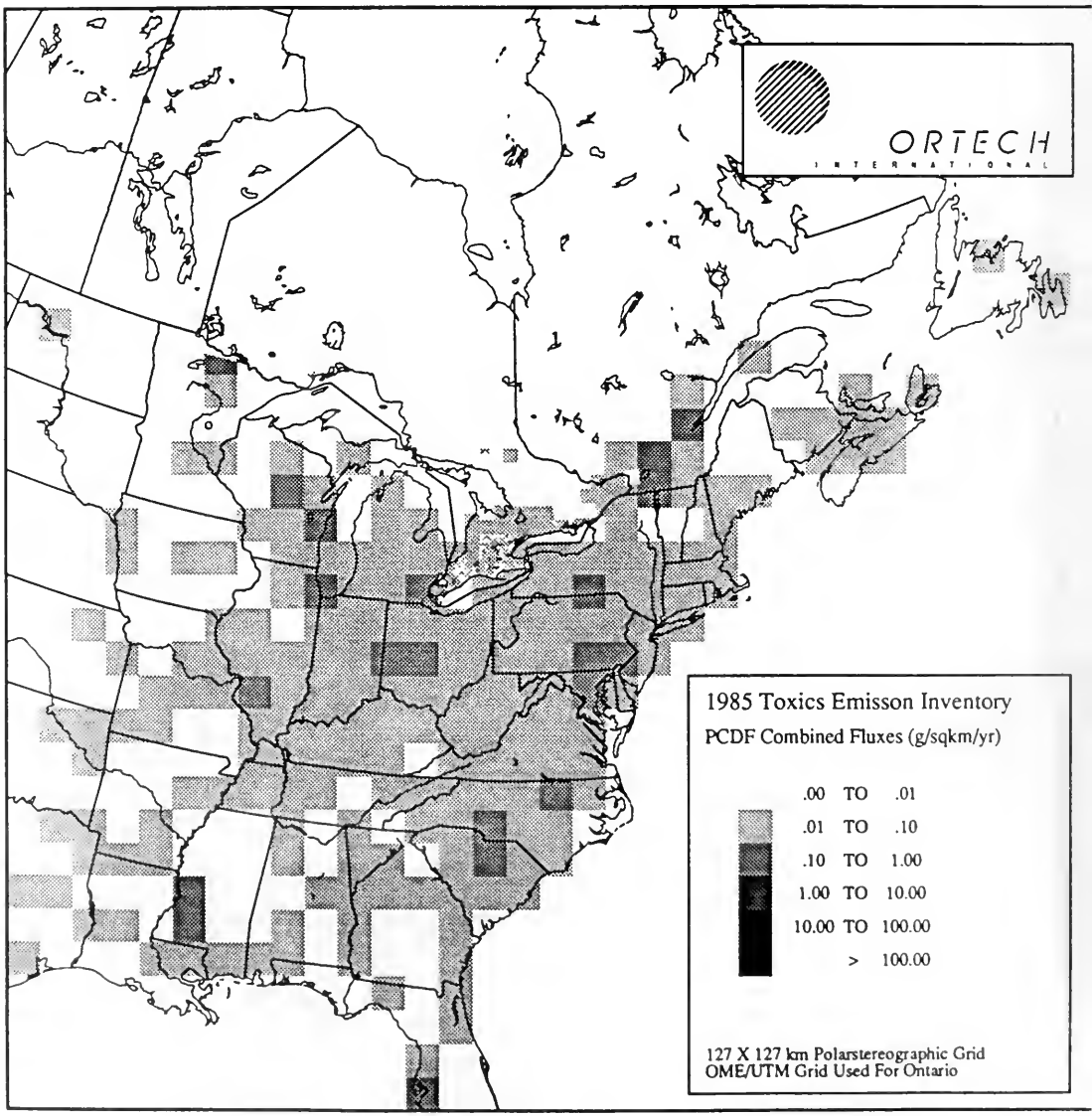


FIGURE 3b

Annual Emissions of PCDF (Point and Area)
in Ontario

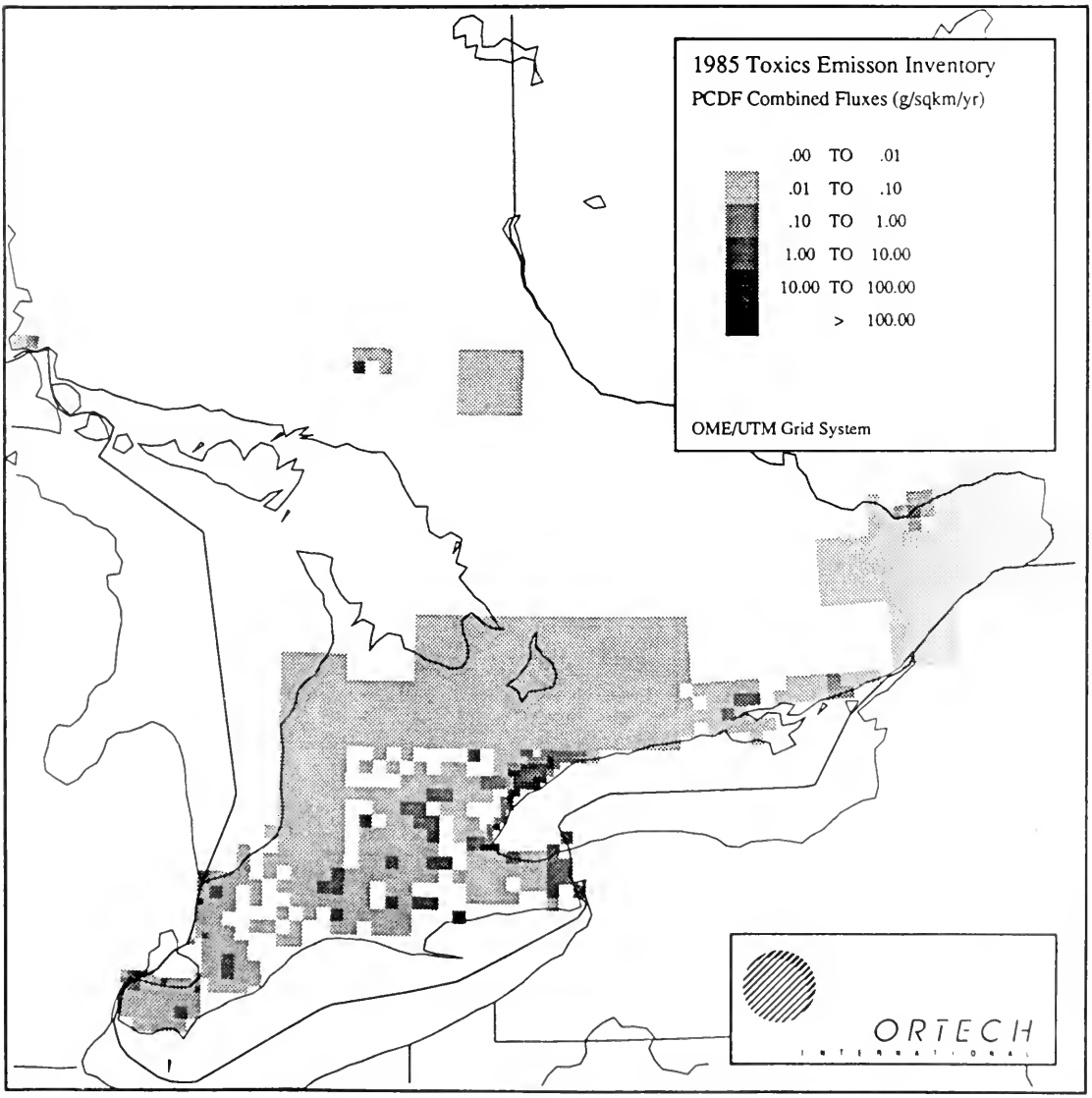


FIGURE 4

Spatial Distribution of Benzene Emissions
Ontario (1985)

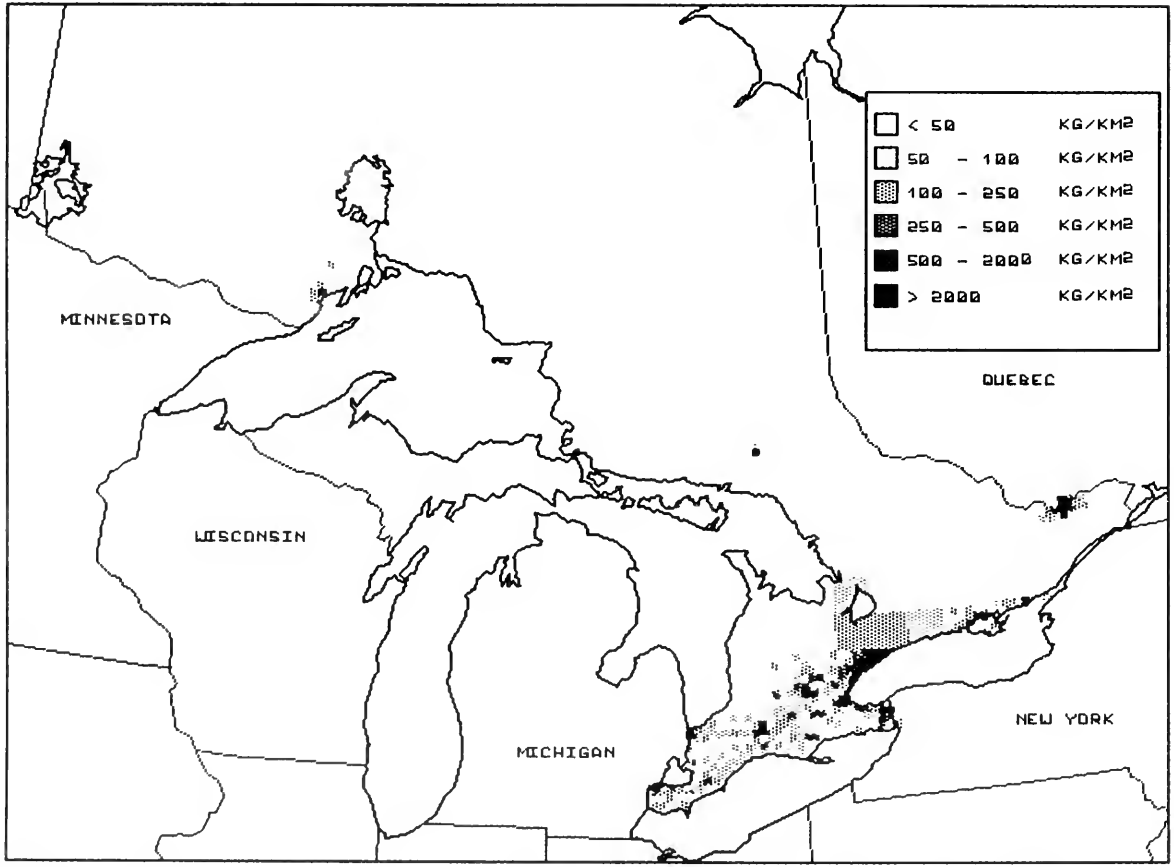


FIGURE 5

Spatial Distribution of Dichloromethane Emissions
Ontario (1985)

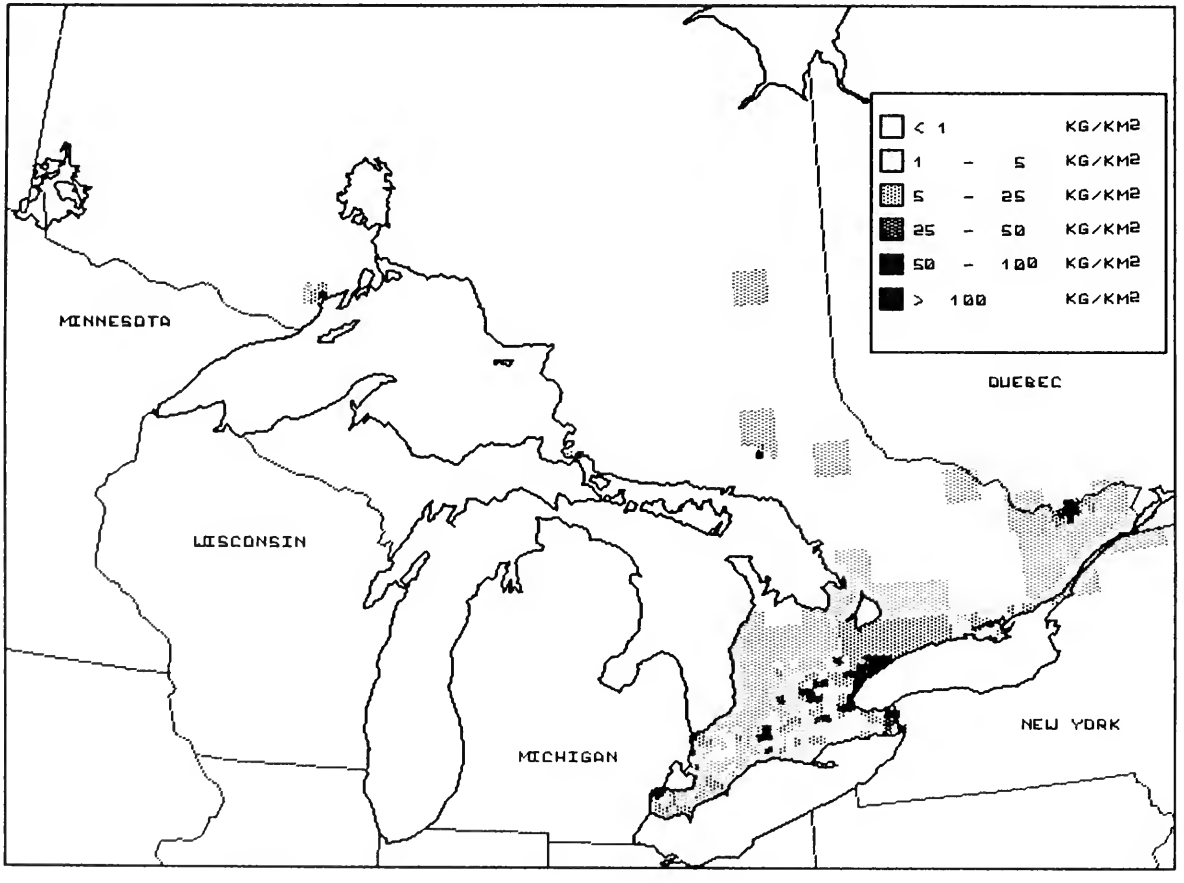


FIGURE 6

Spatial Distribution of Cadmium Emissions
Ontario (1985)

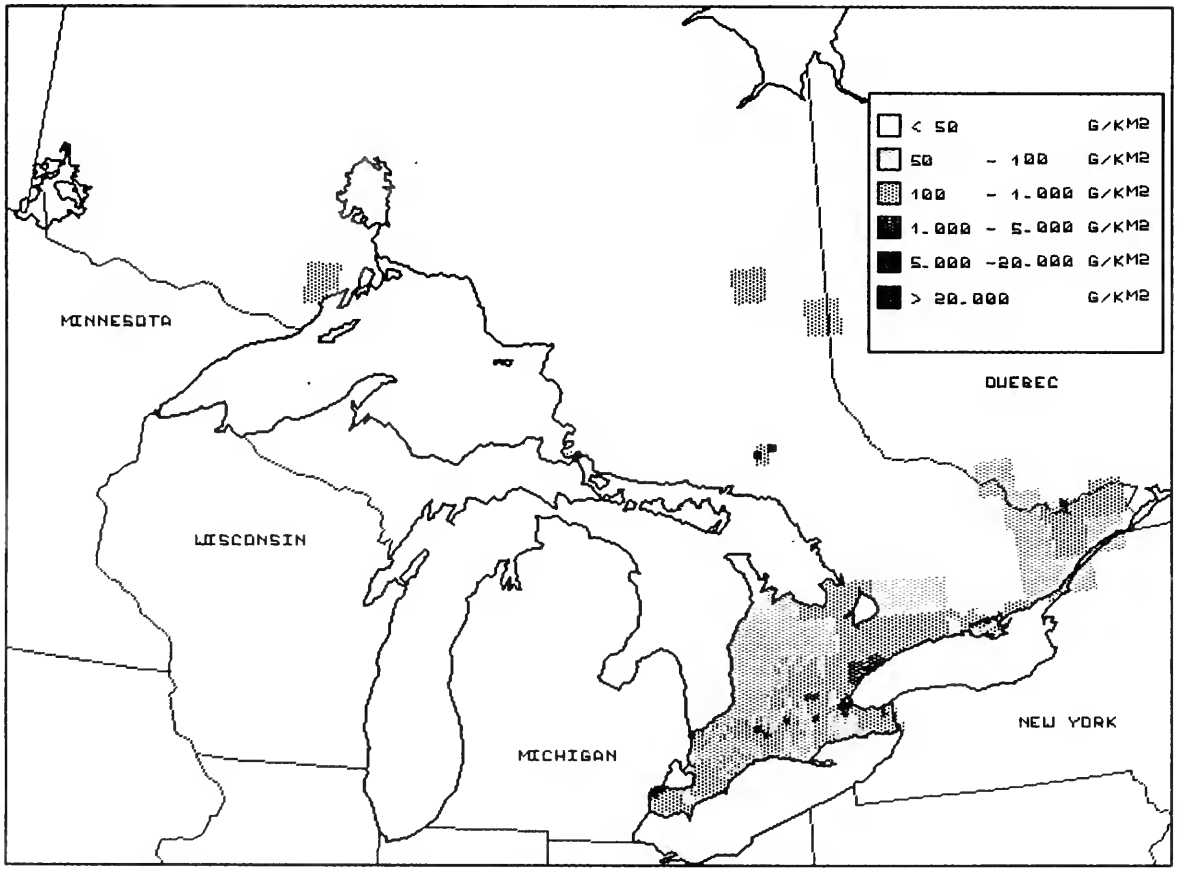
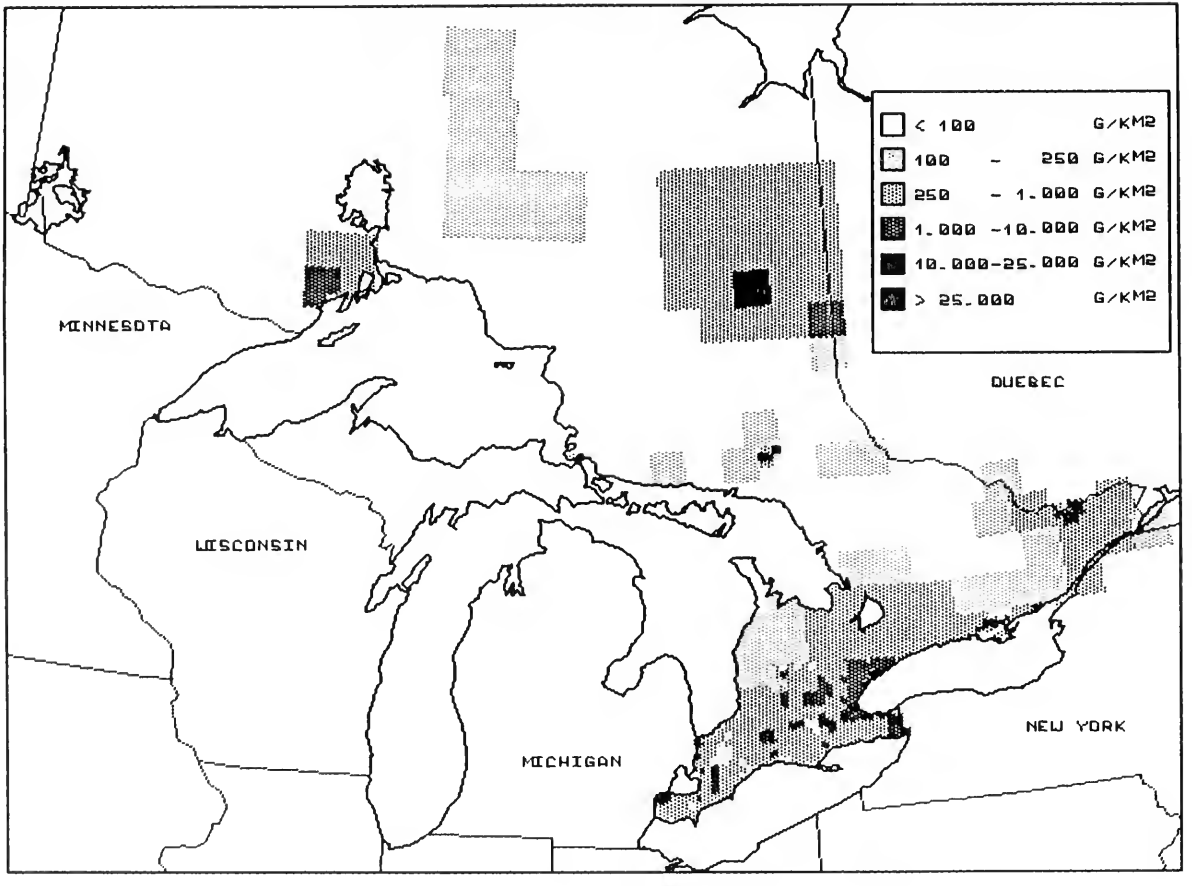


FIGURE 7

Spatial Distribution of Arsenic Emissions
Ontario (1985)



3 ORGANIC CONTAMINANTS IN AMBIENT AIR

This section summarizes some ambient air concentrations of PCDD and PCDF, VOC, and PAH. The PCDD and PCDF data represent the totals of all congeners. VOC surrogates used are Benzene (BZ), Dichloromethane (DCM) and Trichloroethylene (TCE). Benzo(a)Pyrene (B(a)P) is used as a surrogate for PAH. B(a)P is considered to be one of the most toxic of the PAH group.

Recent air concentration data for these contaminants in the Huron Erie Corridor are examined. These data were derived from reports compiled by Environment Canada and the Ontario Ministry of the Environment. Ambient air concentrations for other areas were obtained from the open literature.

Figure 8 identifies sampling sites in the Corridor. As far as is known all sites are operational, however, this map should not be considered definitive but should be used as an overall guide to monitoring sites in this transboundary region. Note that organic contaminants are not monitored at all of the sites shown in Figure 8.

3.1 PCDD and PCDF

Review of the available ambient air data indicates the following: i) highest concentrations of PCDD and PCDF are in urban and industrial areas; ii) urban concentrations are about ten times higher than suburban concentrations; iii) 2,3,7,8-TCDD is generally less than 100 fg/m^3 except in areas where extreme dioxin contamination is present (e.g. Times Beach, MO); iv) 2,3,7,8-TCDF is usually higher than the corresponding 2,3,7,8-TCDD; and v) high concentrations detected in an automobile tunnel suggests automobile emissions contribute PCDD/PCDF to air (Edgerton and Czuczwa, 1989).

Table 1 and Figure 9 present some ambient air PCDD/PCDF concentrations from American and Ontario locations. The Windsor EC and Walpole Island data are from the Environment Canada Detroit Incinerator Monitoring Program Data Report #3 (Environment Canada, 1989). Data for Dorset, Toronto Island, and Windsor MOE are from the Ontario Ministry of the Environment air monitoring program (Steer et al., 1989). Data for American locations were taken from Eitzer and Hites (1989). The order of monitoring locations has been stratified to reflect a gradient from rural to industrial sites.

FIGURE 8

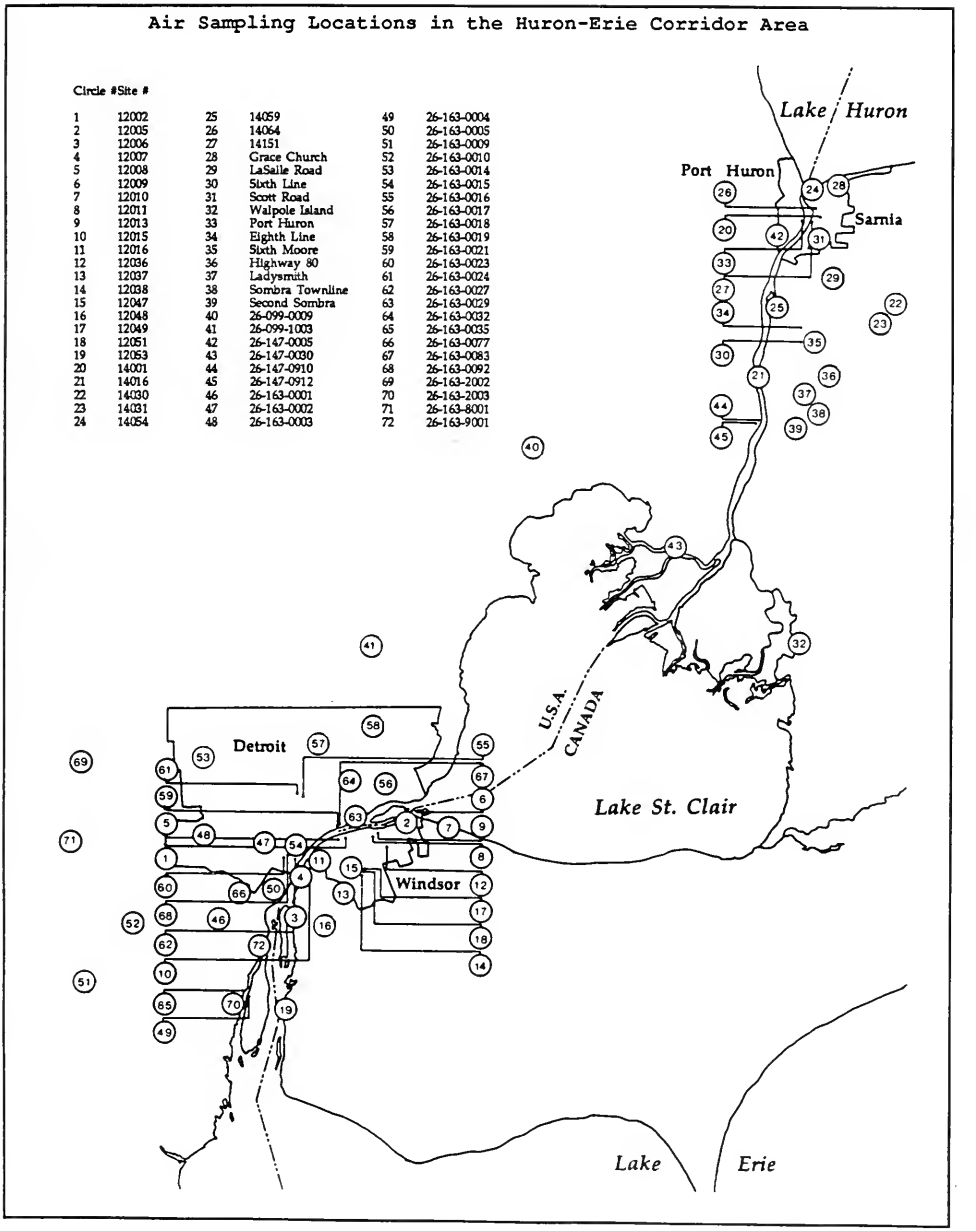
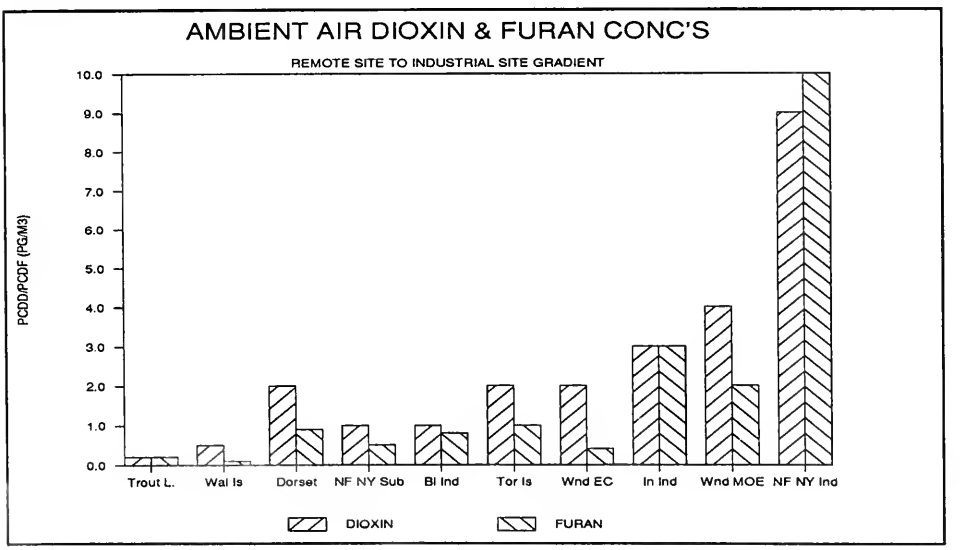

Air Sampling Locations in the Huron-Erie Corridor Area
Circle # Site #
1 12002
2 12005
3 12006
4 12007
5 12008
6 12009
7 12010
8 12011
9 12013
10 12015
11 12016
12 12036
13 12037
14 12038
15 12047
16 12048
17 12049
18 12051
19 12053
20 14001
21 14016
22 14030
23 14031
24 14054
25 14059
26 14064
27 14151
28 Grace Church
29 LaSalle Road
30 Sixth Line
31 Scott Road
32 Walpole Island
33 Port Huron
34 Eighth Line
35 Sixth Moore
36 Highway 80
37 Ladysmith
38 Sombra Townline
39 Second Sombra
40 26-099-0009
41 26-099-1003
42 26-147-0005
43 26-147-0030
44 26-147-0910
45 26-147-0912
46 26-163-0001
47 26-163-0002
48 26-163-0003
49 26-163-0004
50 26-163-0005
51 26-163-0009
52 26-163-0010
53 26-163-0014
54 26-163-0015
55 26-163-0016
56 26-163-0017
57 26-163-0018
58 26-163-0019
59 26-163-0021
60 26-163-0023
61 26-163-0024
62 26-163-0027
63 26-163-0029
64 26-163-0032
65 26-163-0035
66 26-163-0077
67 26-163-0083
68 26-163-0092
69 26-163-2002
70 26-163-2003
71 26-163-8001
72 26-163-9001
Lake Huron
Port Huron
Sarnia
Detroit
Windsor
U.S.A.
CANADA
Lake St. Clair
Lake
Erie

TABLE 1: Ambient Air Dioxin and Furan Concentrations from Selected American and Ontario Locations (results in pg/m^3 to one significant figure)

Site	Total PCDD	Total PCDF
Trout Lake	0.2	0.2
Walpole Island	0.5	0.1
Dorset	2	0.9
Suburban (Niagara Falls, N.Y.)	1	0.5
Bloomington, Indiana	1	0.8
Toronto Island	2	1
Windsor (Environment Canada)*	2	0.4
Indianapolis, Indiana	3	3
Windsor (Environment Ontario)*	4	2
Industrial (Niagara Falls, N.Y.)	9	10

* Samples were collected at different time periods.

FIGURE 9



3.2 Volatile Organic Compounds (VOC)

Ambient air VOC concentrations for Windsor, Sarnia and other Canadian locations are presented in Table 2 and Figure 10. The data are from an unpublished paper by Dann et al. (Sept. 1989). The three compounds used as surrogates for VOC are benzene, dichloromethane, and trichloroethylene. Table 2 and Figure 10 present the VOC data.

TABLE 2: Mean Ambient Air Concentrations of Benzene, Dichloromethane and Trichloroethylene in Canadian Cities (ug/m^3)

Site	Benzene	Dichloromethane	Trichloroethylene
Windsor	3.8	1.5	0.5
Sarnia	4.2	1.3	0.2
Toronto 1	4.1	2.5	0.5
Toronto 2	5.6	5.3	0.3
Toronto 3	2.2	1.4	0.3
Hamilton	6.5	1.8	0.1
Montreal 1	8.6	2.3	0.1
Montreal 2	7.9	4.1	0.2
Vancouver	9.0	3.7	1.0

Toronto 1 = Junction Triangle
Toronto 2 = Edgar Ave.
Toronto 3 = Stouffville
Montreal 1 = Pte aux Trembles
Montreal 2 = 1125 Ontario

3.3 Polycyclic Aromatic Hydrocarbons (PAH)

The PAH data were obtained from two Environment Canada reports: the Detroit Incinerator Monitoring Program Data Report #3 (Environment Canada, 1989) and a report entitled "High-Volume Sampling of Ambient Air Polynuclear Aromatic Hydrocarbons Using Glass Fibre Filters and Polyurethane Foam in Sydney, Nova Scotia" (Environment Canada, 1983). The Nova Scotia site was only 750 metres from the SYSCO coke ovens and should not be considered typical of ambient air. The data are included for comparison only.

Table 3 shows B(a)P and total PAH from Windsor and Walpole Island up to September 1988. Mean B(a)P concentrations are compared with those reported for other North American locations in Table 4 and Figure 11. Note that the mean B(a)P concentration in Windsor is higher than in Toronto and Vancouver and equivalent to Montreal and Los Angeles.

TABLE 3: Total PAH and B(a)P Results (ng/m^3) from Windsor and Walpole Island

Windsor (55 sampling days: Jul. 1987 to Sept. 1988)

	Mean	Median	Max.	Min.
B(a)P	0.61	0.37	3.32	0.05
Total PAH	89.2	65.3	350.7	21.1

Walpole Island (26 sampling days: Jan. 1988 to Sept. 1988)

	Mean	Median	Max.	Min.
B(a)P	0.06	0.06	0.19	N.D.
Total PAH	8.06	6.74	31.2	2.84

Note: Total PAH represents the sum of 26 PAH compounds

TABLE 4: Mean B(a)P Concentrations (ng/m^3) at Several Locations in North America.

Site	No. of Samples	Sampling Period	Mean Conc.
Walpole Is.	26	88/01 to 88/09	0.06
Windsor	55	87/07 to 88/09	0.6
Toronto	42	84/10 to 86/07	0.3
Montreal	29	84/10 to 86/05	0.6
Vancouver	14	85/02 to 85/03	0.3
Sydney, N.S.	16	82/08 to 82/12	1.3[a]
Newark, N.J.	30	summer of 1982	0.2[b]
Columbia, S.C.	13	82/02 to 83/04	0.5
Los Angeles	1000	82/08 to 82/12	0.6

[a] 750m from SYSCO coke ovens
[b] Geometric Mean

FIGURE 10

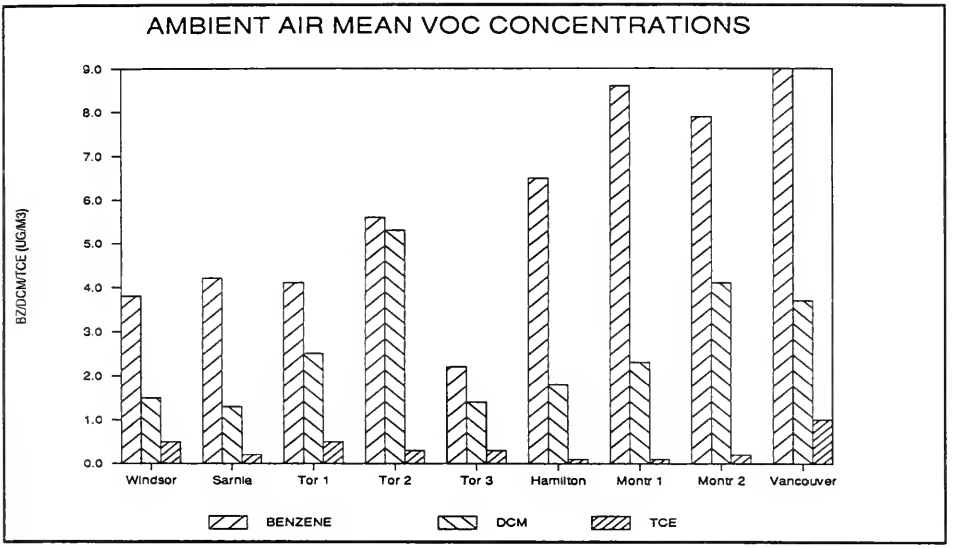
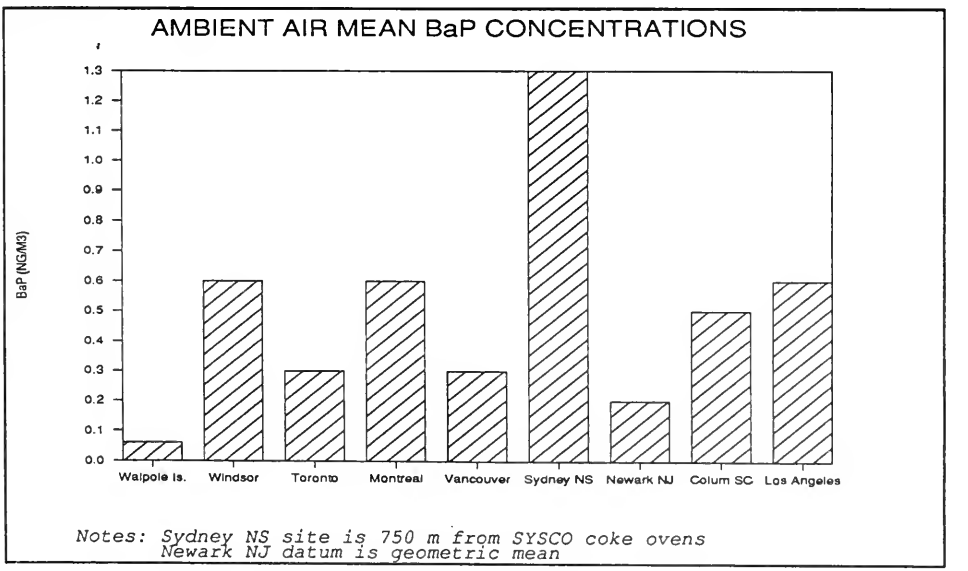


FIGURE 11



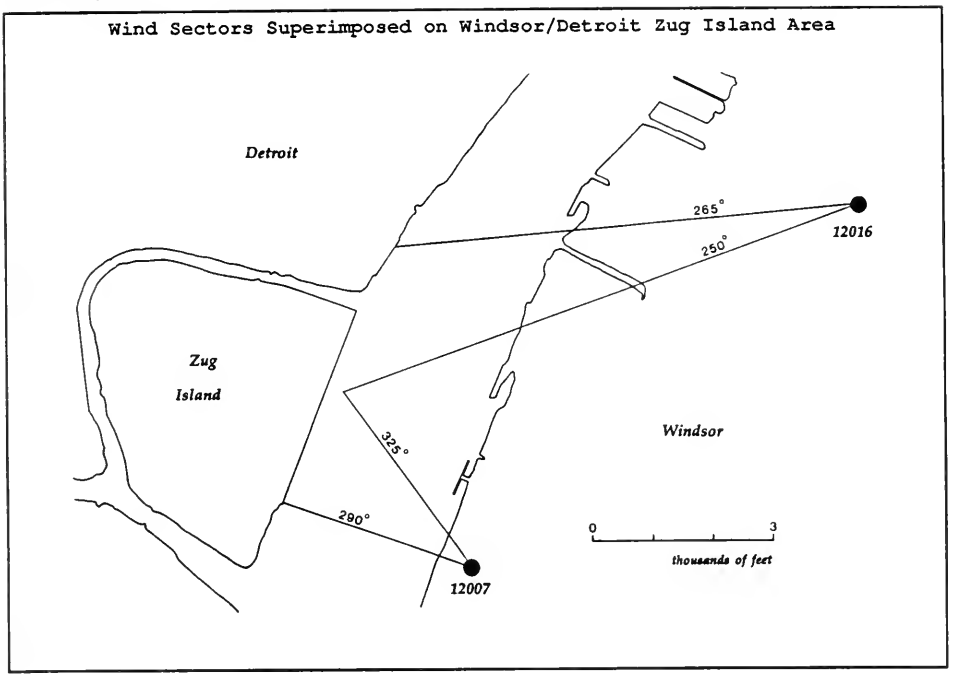
3.4 Preliminary Meteorological Analysis Applied to Organic Compounds and Total Reduced Sulphur

An examination of hourly wind speed and direction in conjunction with measurements of total reduced sulphur (TRS) compound concentrations in West Windsor indicates that the Zug Island area of Detroit has an impact on air quality in the West Windsor area. Table 5 and Figure 12 show that, as the wind shifts, elevated TRS compound concentrations can be "tracked" from one monitoring site to another and the wind directions when projected back, pass over Zug Island. The TRS compound concentrations measured in Windsor were appreciably higher than those measured in Hamilton and Sault Ste. Marie; two Ontario cities with steel mills (Grosse, 1989).

Table 5: TRS Compound Concentrations and Meteorological Information for Two Sites in Windsor (12007 and 12016) on February 26, 1989

Hour of Day (EST)	Wind Speed (km/h)	Wind Direction (°)	TRS 12007 (ppb)	TRS 12016 (ppb)
0100	23	254	2	17
0200	16	263	1	15
0300	16	266	1	16
0400	14	249	1	10
0500	15	248	1	3
0600	14	244	1	2
0700	16	256	1	4
0800	17	259	1	6
0900	19	280	2	3
1000	26	300	38	1
1100	31	315	53	1
1200	33	314	66	1
1300	35	308	60	1
1400	35	313	54	1
1500	36	301	30	1
1600	32	303	59	1
1700	30	299	32	1
1800	31	294	17	1
1900	28	285	7	1
2000	31	280	2	1
2100	31	282	2	1
2200	33	290	2	0
2300	34	288	2	0
2400	33	289	2	1

FIGURE 12



This would suggest that other compounds emitted by the Zug Island steel mills are impacting the West Windsor area. This contention is supported by simultaneous measurements of TRS compounds and B(a)P at site 12007 in West Windsor. Table 6 and Figure 13 and Table 7 and Figure 14 show TRS measurements during two 24 hour periods. PAH samples were also collected during these periods. For several hours on both days, TRS compound concentrations increased above the normal background of 0 to 2 ppb, and B(a)P concentrations were 6.2 and 10.0 ng/m^3. These concentrations are considerably higher than any provisional guidelines for B(a)P which are:

3.3 ng/m^3 - one half hour average for a single source
1.1 ng/m^3 - 24 hour average for a single source
0.3 ng/m^3 - annual average for all sources
0.2 ng/m^3 - annual average for a single source

Table 6: TRS Compound Concentrations and Meteorological Information for Site 12007 in Windsor between 12:00 90/04/11 and 12:00 90/04/12

Day	Hour (EST)	Wind Speed (km/h)	Wind Direction (°)	TRS 12007 (ppb)
11	1200	9	296	-
	1300	12	288	-
	1400	12	287	2
	1500	14	306	1
	1600	14	295	2
	1700	14	309	1
	1800	12	297	2
	1900	15	300	1
	2000	13	309	1
	2100	13	311	4
	2200	12	301	7
	2300	12	309	5
	2400	8	3	1
12	0100	4	24	1
	0200	0	0	2
	0300	7	305	7
	0400	9	297	10
	0500	10	303	7
	0600	9	304	7
	0700	8	303	6
	0800	7	315	3
	0900	5	331	2
	1000	4	291	3
	1100	8	273	0
	1200	9	263	0

Note: Over the same period B(a)P concentration was 6.2 ng/m^3.

Table 7: TRS Compound Concentrations and Meteorological Information for Site 12007 in Windsor between 12:00 90/05/01 and 12:00 90/05/02

Day	Hour (EST)	Wind Speed (km/h)	Wind Direction (°)	TRS 12007 (ppb)
01	1200	9	266	1
	1300	14	256	1
	1400	15	255	1
	1500	19	262	0
	1600	19	251	0
	1700	21	275	1
	1800	21	274	1
	1900	21	280	1
	2000	19	283	1
	2100	18	280	0
	2200	15	287	3
	2300	12	297	9
	2400	14	295	11
02	0100	9	298	16
	0200	6	269	6
	0300	7	263	2
	0400	7	262	1
	0500	6	257	1
	0600	9	268	1
	0700	5	271	2
	0800	3	315	3
	0900	2	350	2
	1000	1	357	1
	1100	1	44	1
	1200	0	0	1

Note: Over the same period B(a)P concentration was 10.0 ng/m^3.

FIGURE 13

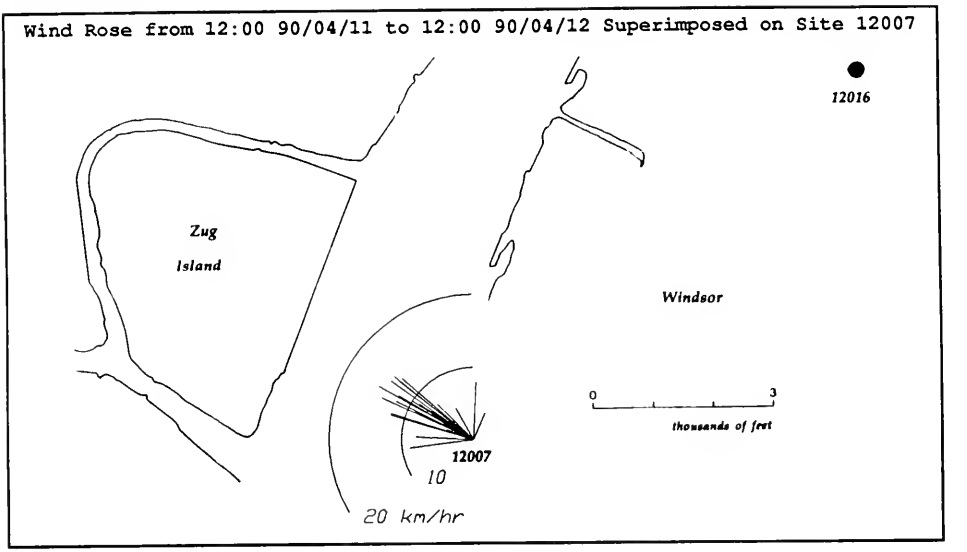
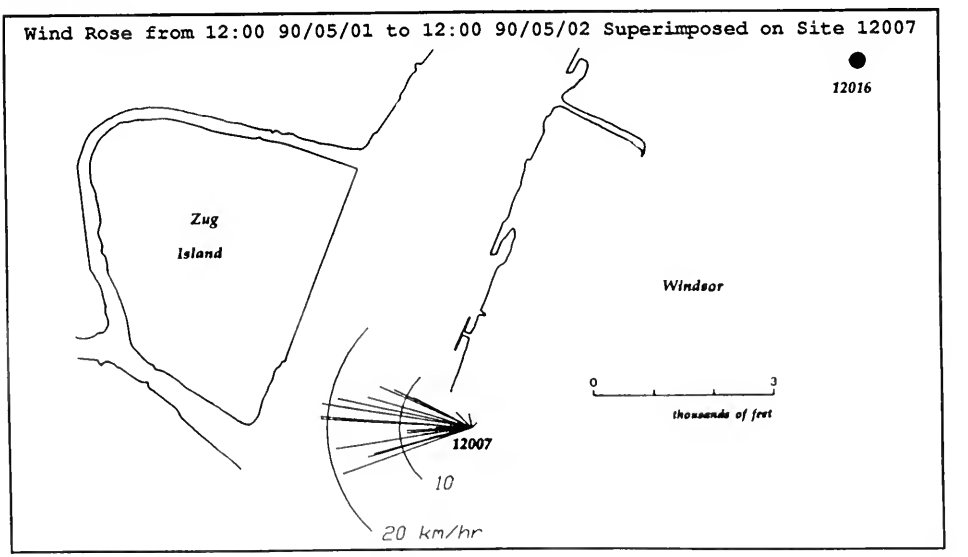


FIGURE 14



The analysis presented above is graphic but limited. In an attempt to better understand the potential impact of Detroit on Windsor air quality, organic compound measurements from site 12008 (downtown Windsor) were stratified by year and concentration. For each pollutant of interest, the highest and second highest 24 hour concentration for each year of data were selected and 24 hour wind roses were generated using meteorological data from Windsor International Airport (Table 8 and Figures 15-17). For VOC, validated data for 1987 and 1988 are unavailable. The analysis was limited to years where a minimum of seven analytical results were available.

When air flows are predominantly from a sector of interest this method may be used to select days of expected high pollutant concentrations for further analysis. When the wind direction is variable, even general observations about pollutant origin are not warranted.

TABLE 8: Highest and Second Highest Concentrations of Targeted Pollutants in Windsor

Year		PCDD+PCDF pg/m^3	B(a)P ng/m^3	Benzene ug/m^3	DCM ug/m^3	TCE ug/m^3
1987	First		3.3(12/23)			
	Second		1.9(11/17)			
1988	First	8.3(02/03)	6.3(11/17)			
	Second	4.0(12/17)*	5.2(12/15)			
1989	First		3.2(02/27)	12.3(04/22)	13.9(04/22)	0.5(04/22)
	Second		1.1(01/16)	11.2(09/25)	7.9(03/23)	0.4(03/23)

* = 48 hour sample starting 12/17
Numbers in parentheses refer to the month/day of sample.

The VOC values may be compared to the urban average of means (Dann et al., 1989) for Benzene (6.0 ug/m^3); Dichloromethane (2.7 ug/m^3); and Trichloroethylene (0.25 ug/m^3).

Explanatory notes for Figures 15 to 17

1. *n = the number of samples from which the highest and second highest concentrations were selected*

2. *When the wind is from the same direction for more than one of 24 hours, the average speed is plotted and the number of hours is shown at the end of the direction/speed vector*

3. *The second highest dioxin/furan concentration in 1988 was a 48 hour sample*

FIGURE 15

Wind Roses for the Highest and Second Highest PCDD and PCDF (Total) Concentrations Measured in Windsor, 1988

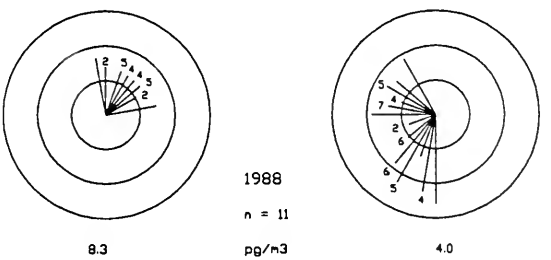


FIGURE 16

Wind Roses for the Highest and Second Highest Benzo(a)Pyrene B(a)P Concentrations Measured in Windsor, 1987 - 1989

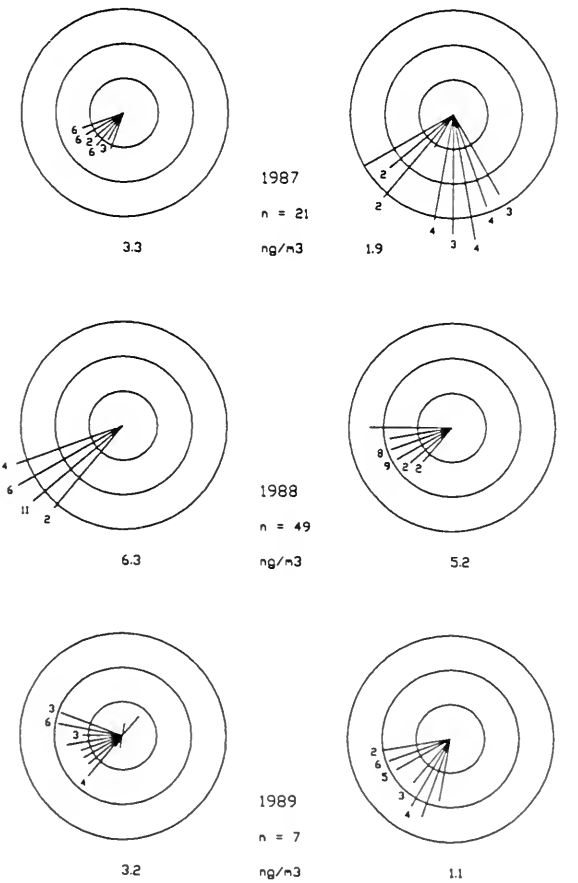


FIGURE 17

Wind Roses for the Highest and Second Highest Benzene, Dichloromethane and Trichloroethylene Concentrations Measured in Windsor, 1989

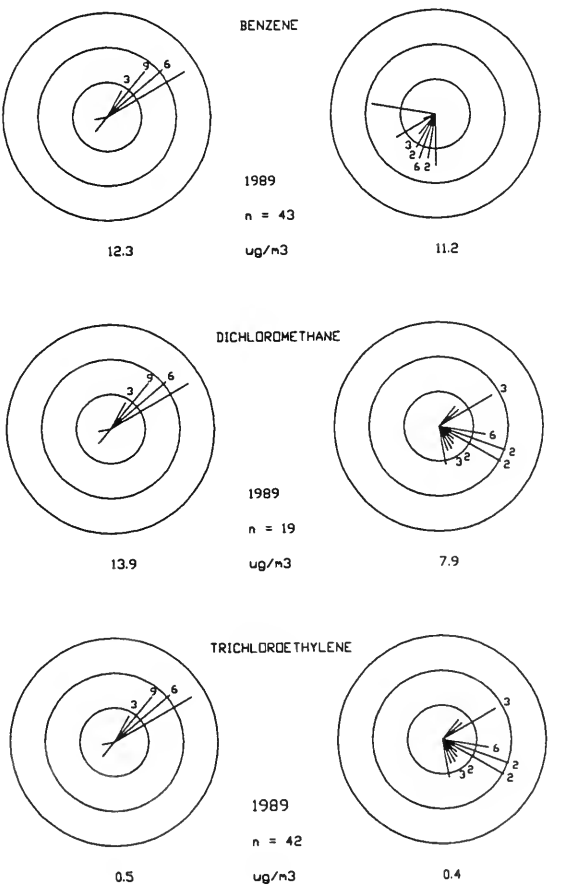


Table 9 shows the number of samples, and the average, maximum, and minimum concentration by wind sector for PCDD, B(a)P, and Benzene measured at site 12008 in downtown Windsor. Dichloromethane and trichloroethylene results are not included because validated data are unavailable for 1987 and 1988. The table clearly shows higher PCDD concentrations when winds are from the N and NNE. For B(a)P, the general trend shows higher concentrations with winds from the S to W quadrant. The pattern for benzene is less clear. The high values are generally associated with winds from the S to W quadrant, however, the highest concentration occurred during NE flows and the average concentrations are generally similar for all sectors. A larger data base and a moe detailed meteorological analysis is necessary.

Table 9: Concentrations of PCDD, B(a)P and Benzene Measured Over Three Years at Site 12008 (Downtown Windsor) Stratified by Wind Direction

	PCDD				B(a)P				Benzene			
Prevailing Wind Direction	NUM	AV.	MAX	MIN	NUM	AV.	MAX	MIN	NUM	AV.	MAX	MIN
N	3	4.9	10.4	1.0	4	0.4	0.5	0.2	8	2.7	4.6	2.0
NNE	1		7.1		1		0.3		1		2.7	
NE					5	0.2	0.7	0.1	9	3.5	12.3	1.6
ENE					2	0.3	0.3	0.2	2	2.5	2.7	2.3
E					4	0.3	0.5	0.1	6	2.5	3.2	1.6
ESE	2	1.4	1.7	1.1	2	0.2	0.3	0.1	2	4.2	4.5	3.9
SE												
SSE					1		0.2		2	2.9	3.8	2.0
S	4	1.5	2.3	0.6	10	0.8	1.8	0.2	12	3.8	5.7	2.0
SSW	1		1.1		10	0.6	1.1	0.1	18	4.8	8.2	1.8
SW	3	1.4	2.6	0.1	9	1.5	2.5	0.2	11	3.6	4.7	1.6
WSW					4	4.9	6.3	0.2	12	4.8	8.0	2.8
W	4	1.1	2.2	0.4	9	0.9	3.2	0.2	16	4.4	8.8	1.8
WNW					5	0.2	0.3	0.1	5	3,8	3.9	1.8
NW									3	3.5	4.8	2.6
NNW					2	0.5	0.6	0.3	2	2.1	2.2	2.1

3.5 Limitations of the Analysis

1. Only a very limited number of pollutants have been examined.

2. Hourly stratification of the available organic data is not possible. It may be possible to collect hourly VOC samples for comparison with wind speed and direction data and criteria pollutant levels. However, hourly B(a)P and dioxin/furan data are not possible due to the large sample size required to achieve suitable detection limits.

3. Because the organics data are integrated over 24 hours, it is not possible from this cursory meteorological analysis to arrive at firm conclusions regarding pollutant origin.

4. Only examining the highest/second highest concentrations from a very limited data set does not give a good overall picture of either air quality or pollutant origin.

5. A lack of isomer-specific data for the dioxin results precludes a comparison of ambient air concentrations with toxic equivalents which would be necessary to determine potential health impacts.

4 AIR QUALITY IN WINDSOR, SARNIA AND OTHER ONTARIO CITIES

Air Quality data for 1988 in five cities in Ontario, namely; Windsor, Sarnia, Hamilton, Toronto, and Sudbury are examined. The ranges in annual means for the monitoring stations in each city and exceedances of the 1-hour, 24-hour and annual Air Quality Criteria (AQC) are compared. Pollutants considered in this analysis are ozone (O_3), sulphur dioxide (SO_2), total suspended particulate (TSP), lead (Pb), chromium (Cr) and cadmium (Cd).

4.1 Ozone (O_3)

The range of O_3 summer month (June, July, August) means in the five cities is shown in Figure 18a. The highest annual mean was recorded in Sudbury. The range of one hour O_3 exceedances above the provincial AQC of 80 ppb is shown in Figure 18b. Windsor recorded the highest number of hourly exceedances.

4.2 Sulphur Dioxide (SO_2)

The range of SO_2 annual means as recorded at the monitoring stations for the five cities are shown in Figure 19. All stations were in compliance with the annual provincial annual Air Quality Criteria (0.02 ppm). No exceedances of the 1-hour SO_2 criterion were recorded in Windsor, Sarnia, Hamilton or Toronto. Several such exceedances were recorded in Sudbury. The 24-hour SO_2 criterion was exceeded on one occasion in Sarnia and on several occasions in Sudbury.

4.3 Total Suspended Particulates (TSP)

The TSP in Windsor, Sarnia, Hamilton, and Toronto show annual means near the annual AQC of 60 ug/m^3. Sudbury means are well below the annual AQC (Figure 20a). However the daily AQC for TSP are regularly exceeded. The range in the frequency of daily TSP exceedances are highest and comparable in Windsor and Hamilton. They exceed those of Sarnia, Toronto and Sudbury (Figure 20b).

4.4 Lead (Pb)

The largest range in mean particulate lead in air concentrations is found in Toronto. Annual mean concentrations range from less than 0.05 to 0.5 ug/m^3. Annual Pb concentrations in Windsor and Sarnia are less than 0.1 ug/m^3 (Figure 21). Toronto was the only city to record exceedances of the daily Pb criterion of 5.0 ug/m^3. These were recorded near lead smelting plants.

4.5 Chromium (Cr)

Hamilton had the largest range in mean particulate chromium concentrations followed by Windsor (Figure 22). Toronto, Sudbury and Sarnia annual means are comparable. The 24-hour Cr criterion

of 1.5 ug/m^3) was not exceeded in any city. It must be noted that particulate chromium is frequently below analytical detection limits.

4.6 Cadmium (Cd)

Cadmium levels were comparable in all five cities. Annual means were less than 0.001 ug/m^3. No exceedances of the 24-hour provincial criterion (2.0 ug/m^3) were recorded in 1988.

FIGURE 18a

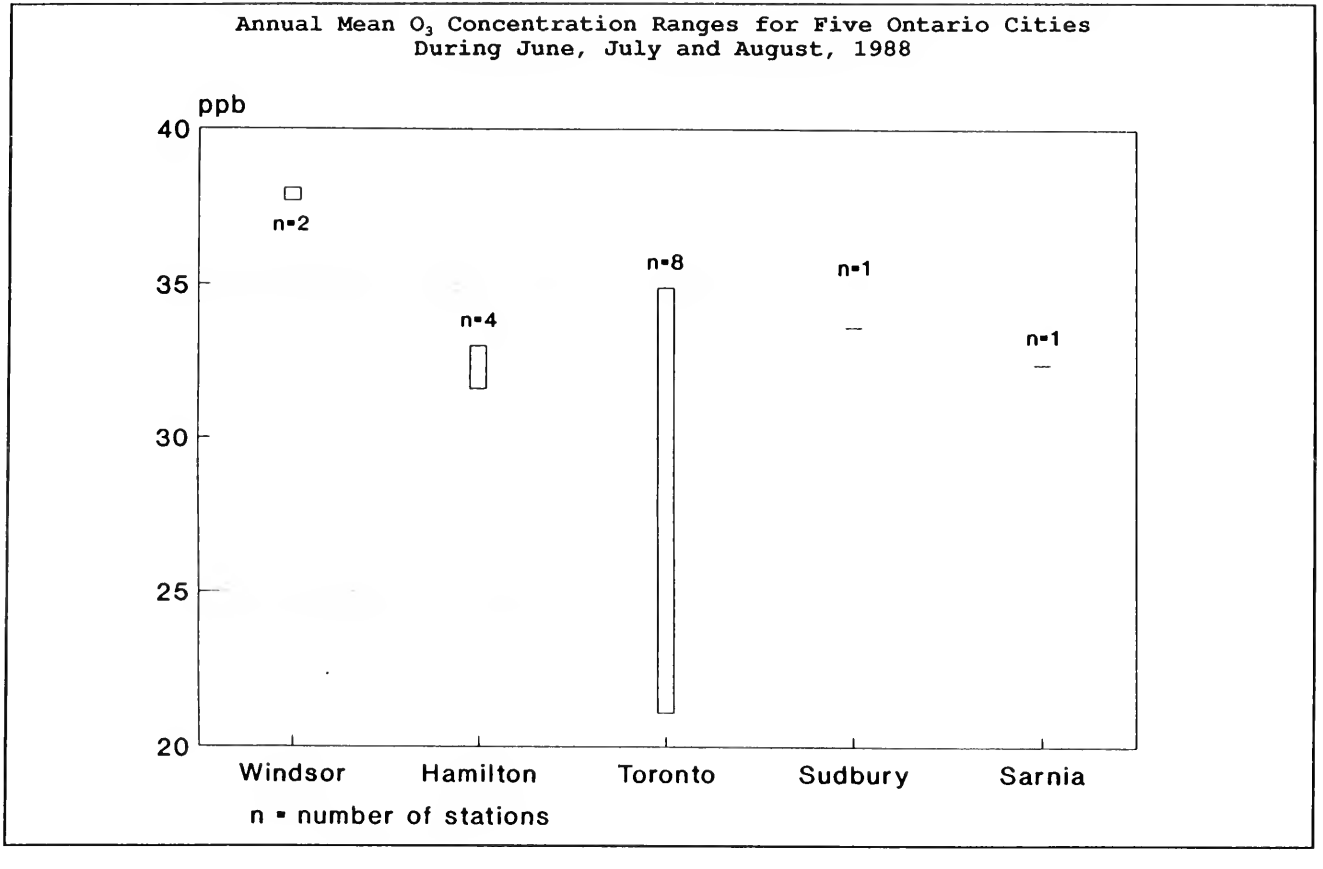

Annual Mean O_3 Concentration Ranges for Five Ontario Cities
During June, July and August, 1988
ppb
40
35
30
25
20
n=2
n=4
n=8
n=1
n=1
Windsor
Hamilton
Toronto
Sudbury
Sarnia
n = number of stations

FIGURE 18b

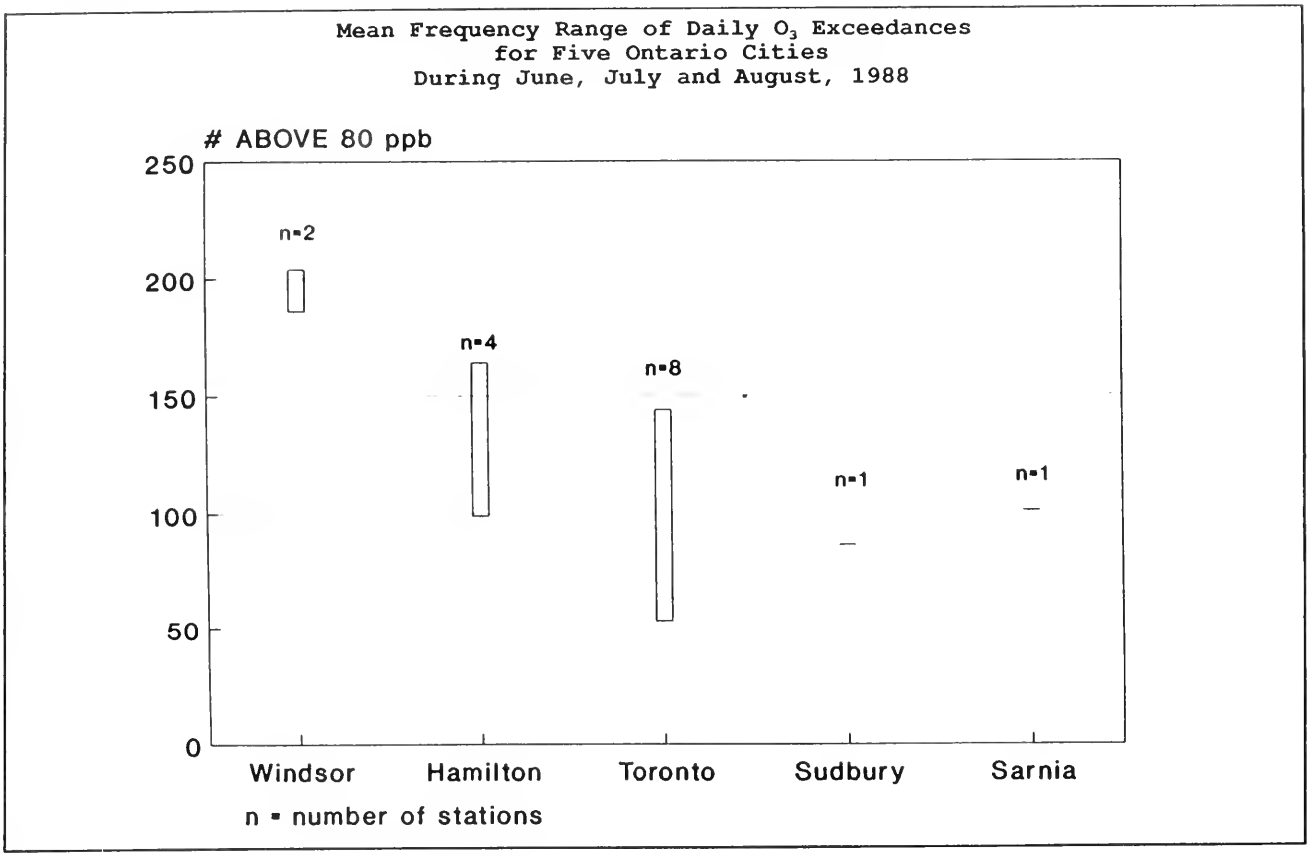

Mean Frequency Range of Daily O_3 Exceedances
for Five Ontario Cities
During June, July and August, 1988
ABOVE 80 ppb
250
200
150
100
50
0
n=2
n=4
n=8
n=1
n=1
Windsor
Hamilton
Toronto
Sudbury
Sarnia
n = number of stations

FIGURE 19

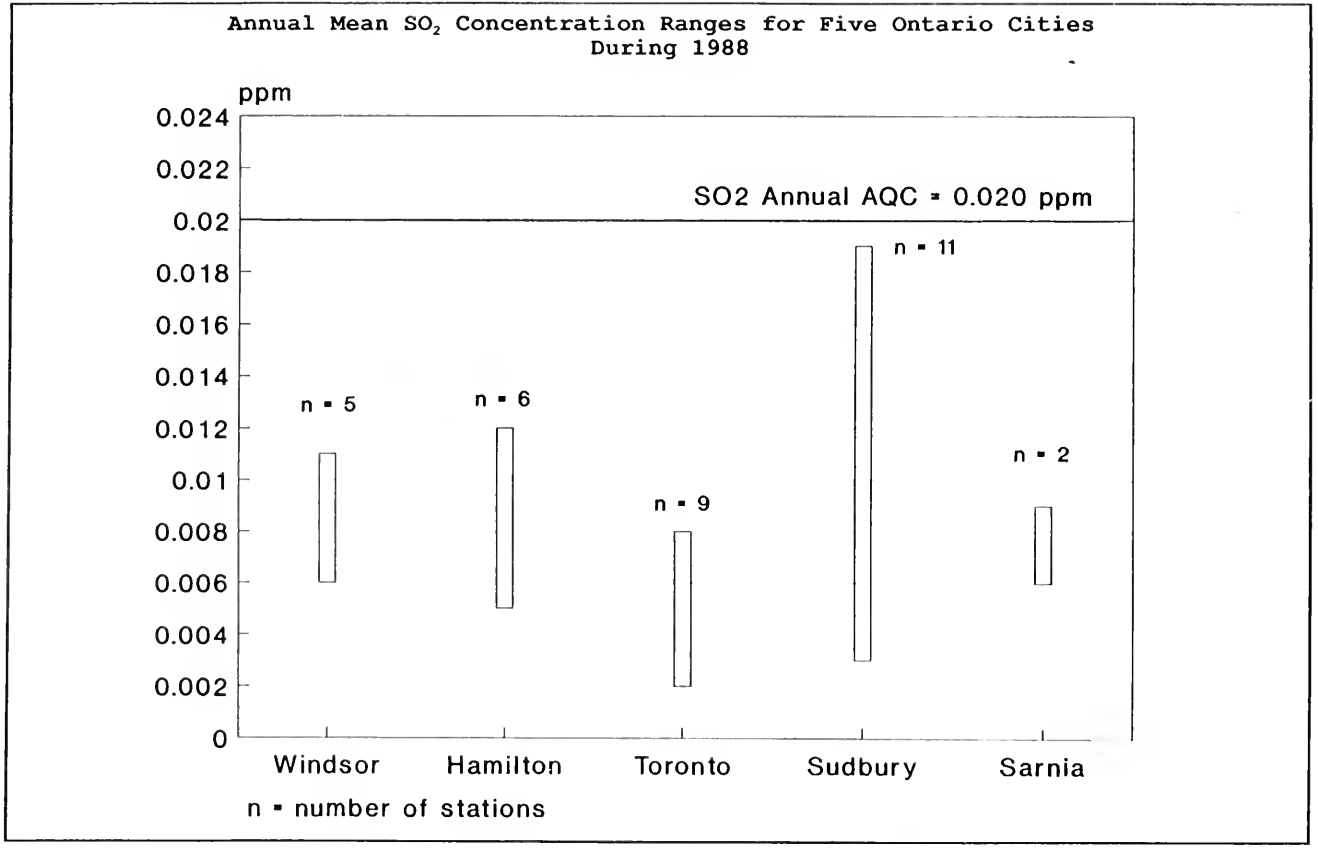

Annual Mean SO_2 Concentration Ranges for Five Ontario Cities During 1988
ppm
0.024
0.022
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
SO2 Annual AQC = 0.020 ppm
n = 5
n = 6
n = 9
n = 11
n = 2
Windsor
Hamilton
Toronto
Sudbury
Sarnia
n = number of stations

FIGURE 20a

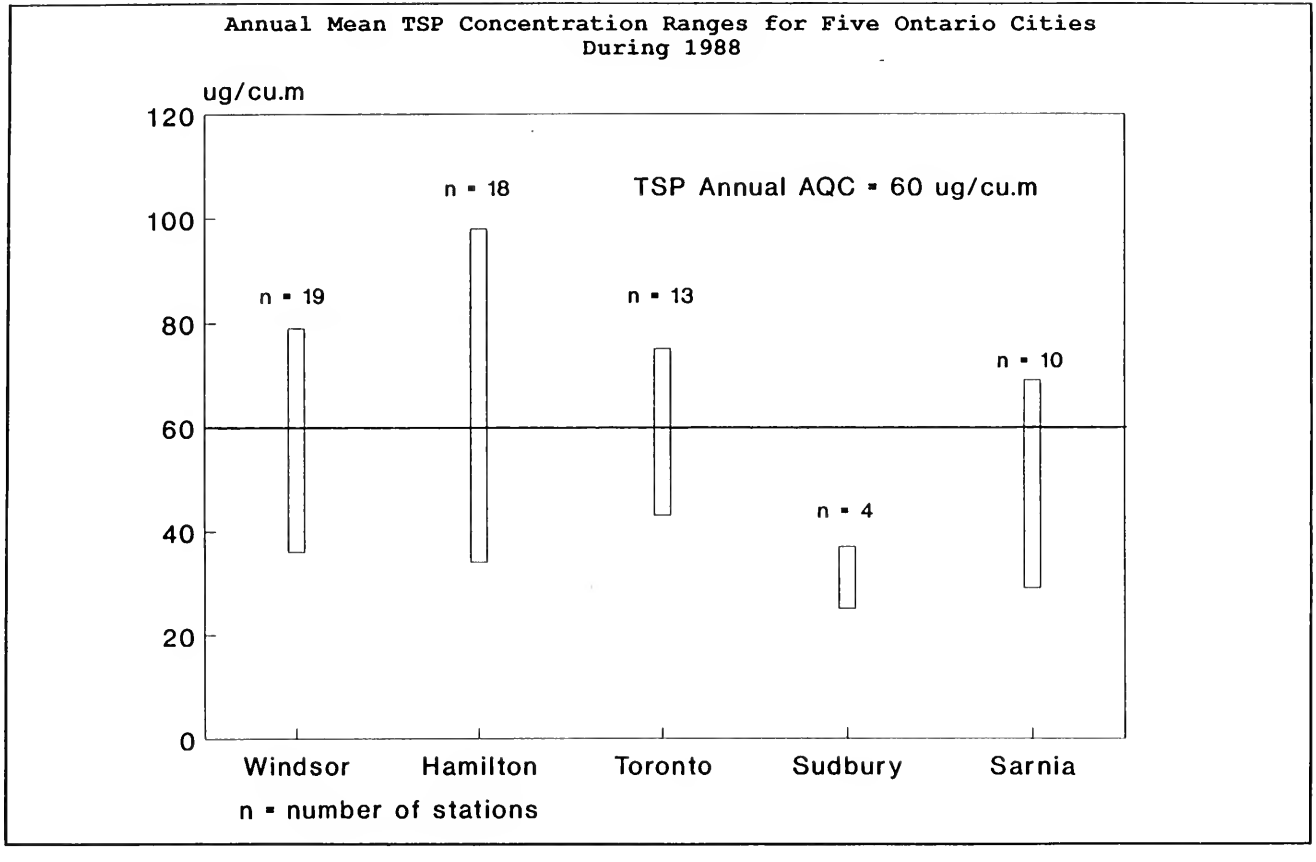

Annual Mean TSP Concentration Ranges for Five Ontario Cities
During 1988
ug/cu.m
120
100
80
60
40
20
0
n = 18
TSP Annual AQC = 60 ug/cu.m
n = 19
n = 13
n = 10
n = 4
Windsor
Hamilton
Toronto
Sudbury
Sarnia
n = number of stations

FIGURE 20b

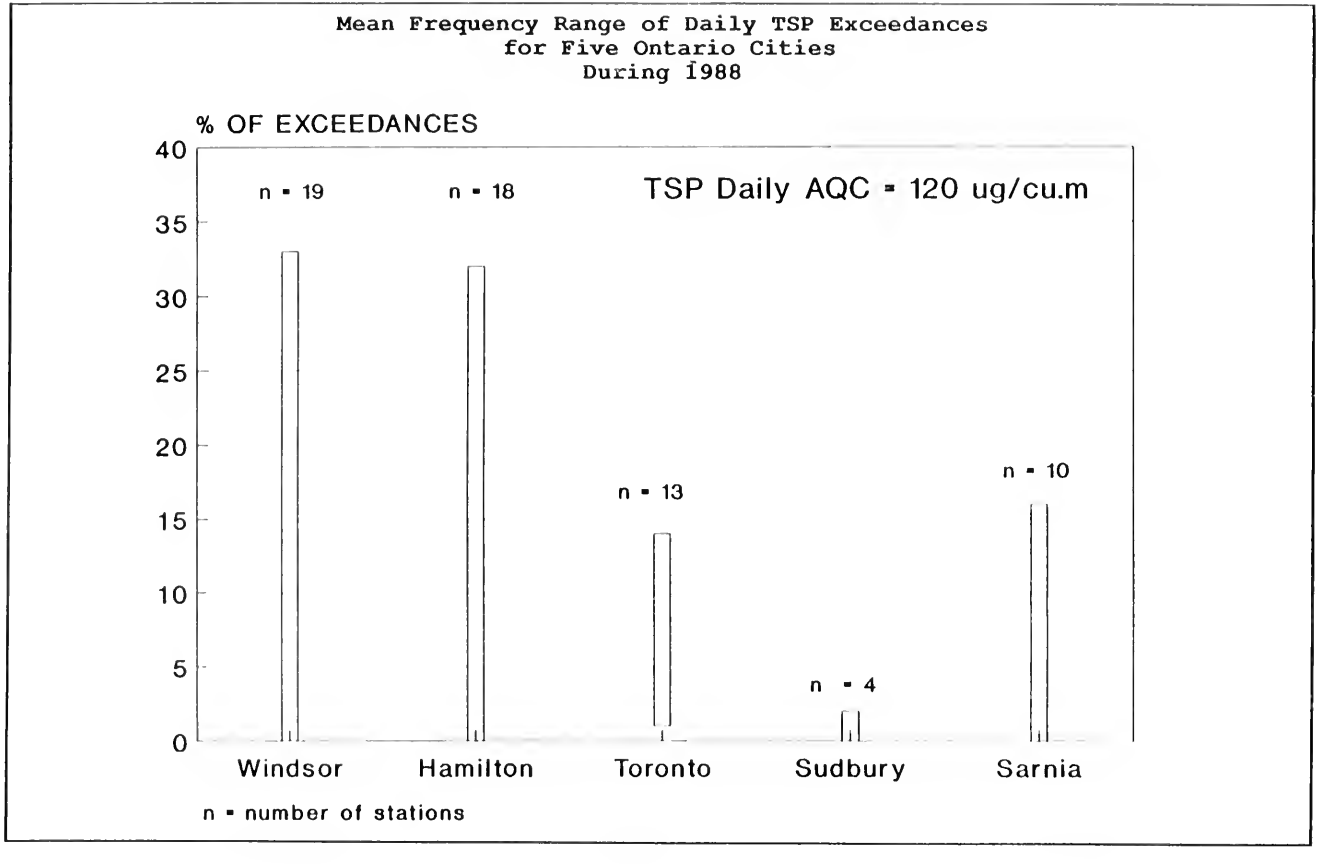

Mean Frequency Range of Daily TSP Exceedances
for Five Ontario Cities
During 1988
% OF EXCEEDANCES
40
35
30
25
20
15
10
5
0
n = 19
n = 18
TSP Daily AQC = 120 ug/cu.m
n = 13
n = 10
n = 4
Windsor
Hamilton
Toronto
Sudbury
Sarnia
n = number of stations

FIGURE 21

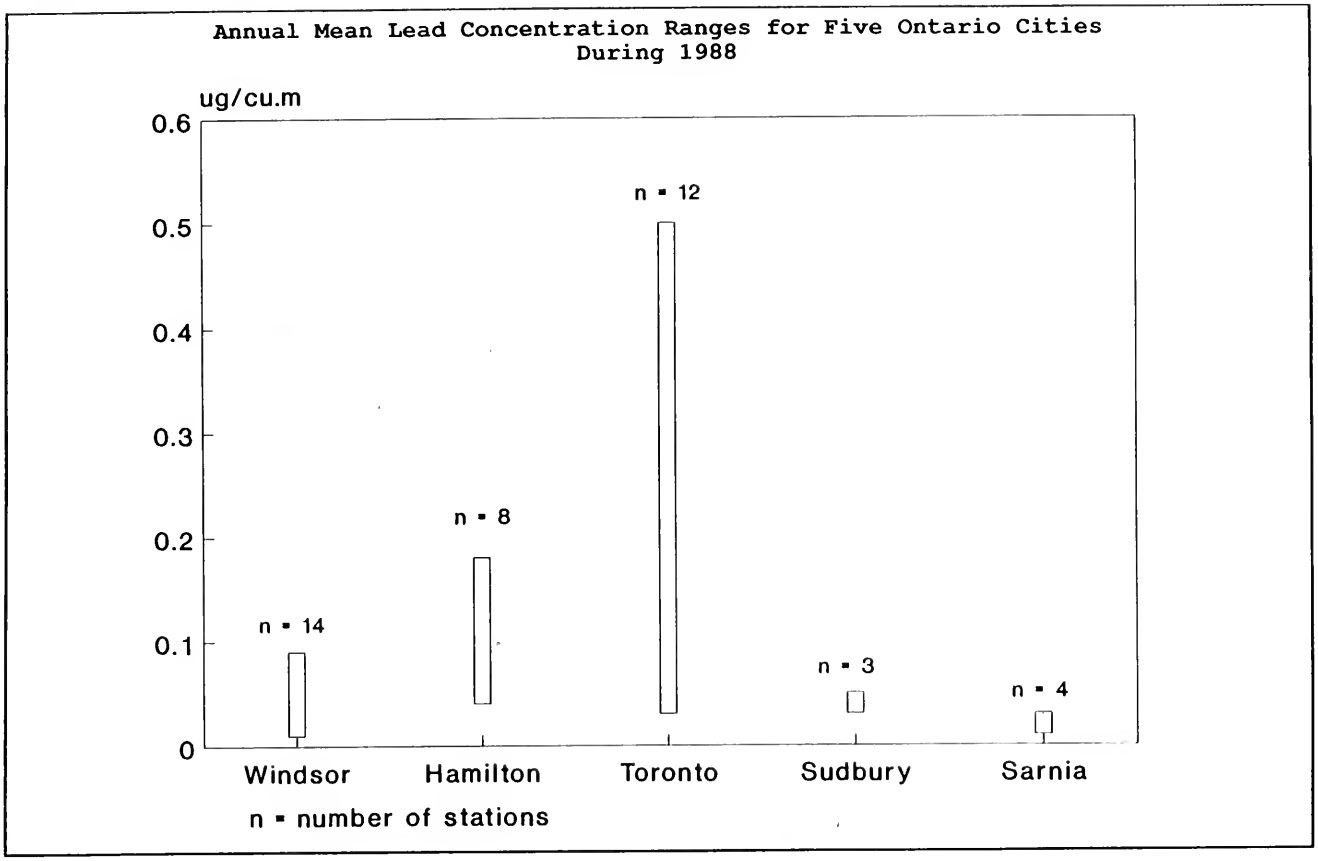
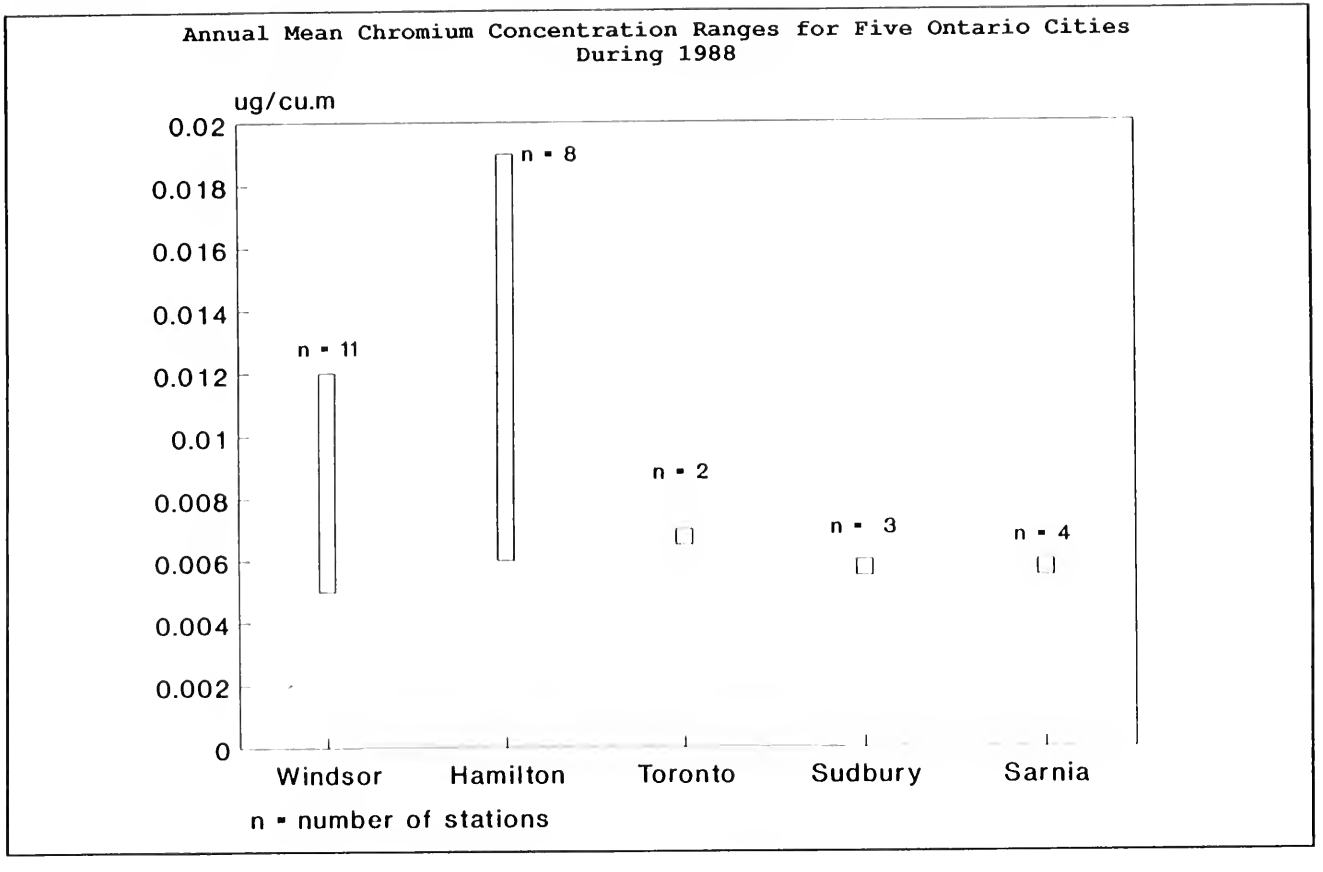

Annual Mean Lead Concentration Ranges for Five Ontario Cities
During 1988
ug/cu.m
0.6
0.5
0.4
0.3
0.2
0.1
0
n = 14
n = 8
n = 12
n = 3
n = 4
Windsor
Hamilton
Toronto
Sudbury
Sarnia
n = number of stations

FIGURE 22


Annual Mean Chromium Concentration Ranges for Five Ontario Cities
During 1988
ug/cu.m
0.02
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
n = 11
n = 8
n = 2
n = 3
n = 4
Windsor
Hamilton
Toronto
Sudbury
Sarnia
n = number of stations

4.7 Population and Pollutant Ranking For Ontario Cities

In Table 10, 25 Ontario cities are listed by population total. The annual average concentrations of SO_2, TSP, Pb and Cr, and summer months average of O_3 are ranked for those cities where the contaminant is monitored. Five years, 1985 through 1989 are considered. Windsor ranks ninth and Sarnia 24 th in population total. However, in the case of both cities, the air pollutant concentrations tend to rank notably higher than their population.

	1985	1986	1987	1988	1989
O_3	6	8	11	10	13
SO_2	6*	1*	3*	2	2
TSP	6	2	4	2	3
Pb	3*	2*	2*	4*	6*
Cr	3*	2*	2*	2*	2

* = tied with another city

4.8 Summary

Based on the preceeding analysis of selected air pollutants with respect to range of annual means, range of 1-hour, 24-hour, and annual exceedances of the provincial AQC; and finally, air pollutant concentration ranking according to population, it would appear that Windsor and Sarnia rank relatively high among Ontario cities for short term exposure to elevated ozone concentrations and long term SO_2 concentrations.

TABLE 10

Ranking of Annual Average Pollutant Concentrations for Ontario Cities

CITY	POPULATION	OZONE					SULPHUR DIOXIDE					TSP					LEAD					CHROMIUM				
		1985	1986	1987	1988	1989	1985	1986	1987	1988	1989	1985	1986	1987	1988	1989	1985	1986	1987	1988	1989	1985	1986	1987	1988	1989
Toronto	597,126	10	14	12	20	12	12	12	9	6	4	6	7	7	7	4	3	2	2	6	4	8	2	2	2	3
North York	544,560				15	18	5	8	17	8	10	14	14	14			3	2	2			3	4	7		
Scarborough	470,406	14	10	7	21	15	14	14	9	6	10	4	5	6	7	2	1	2	2	6	8	3	4	5		
Hamilton	429,466	8	12	13	11	13	3	1	5	3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Mississauga	385,156	13	11	16	17		8	6	2	15	19	3	6	5	4	7	3	2	2	9	8	3	4			
Ottawa	303,747	14	15	18	18	17	17	19	20	22	21															
Etobicoke	293,433	12	7	15	19	20	6	8	8	12	7	2	7	12	4	4	3	2	2	4	2	3	4	6		
London	281,745	2	5	2	3	3	17	14	15	15	10	12	9	2	4	8	3	8	2	3	4	9	9	2	2	3
Windsor	190,198	1	4	5	2	8	6	1	3	2	2	6	2	4	2	3	3	2	2	4	6	3	2	2	2	2
Kitchener	152,771	4	8	10	9	16	17	14	9	20	21	9	4	3	3	4				2	2				5	3
York	131,537				14	21				9	2															
Oshawa	120,904	9	12	9	12	7	14	14	9	9	10	13	12	8	9	8	3	8	2	9	8	2	4			
St. Catharines	120,567	5			4	14	8	8	1	1	10	6	3	10												
Burlington	118,546	6	3	4	22	5	12	12	9	15	7	4	10	9	12	10				14	8					
Thunder Bay	109,296			17	25	24	21	21	21	25	25	14	15	15	15	14	11	8	2	6	8					
Oakville	98,404	10	8	3	15	4	8	8	15	12	10	11	12	11	10	10				14	8					
East York	96,497				24	23				24	16															
Sudbury	89,698	16	15	10	6	6	2	1	3	3	4	17	17	17	18	17	11	8	2	9	6					
Guelph	80,786		1	1	5	11				15	19				14	13				17	15					
Sault Ste Marie	78,586	17	17	14	23	19	11	7	9	15	21	16	16	16	16	15	3	8	2	9	8				5	
Niagara Falls	70,540				1	1	14	14	17	12	16				11	12										
Waterloo	67,435				8	10				20	16															
North Bay	51,313				7	9	17	19	17	22	24	18	17	18	17	18	11	8	2	14	15				8	3
Sarnia	46,448	3	2	6	10	2	1	1	5	3	4	9	10	13	12	15	11	8	3	9	15				5	3
Cornwall	45,529	7	6	8	12	22	3	1	7	9	7															

Note: Ozone data for June, July and August only

5 AN EVALUATION OF VEGETATION AND SOIL CONTAMINANTS

Samples of foliage and soil, when subjected to chemical analysis, are useful "passive monitors" of contaminants in the environment. Although they cannot quantify air quality, they do provide a means of comparing environmental quality in different areas. They offer the additional advantage of integrating the effects of exposure to air contaminant levels over time. They also offer a low acquisition cost for environmental quality data.

The Phytotoxicology Section has collected such samples during the course of numerous investigations. Data from two areas, Windsor and Metropolitan Toronto, are used in this review, primarily because they have been the targets of these investigations, and the data were relatively accessible.

5.1 Windsor

The Phytotoxicology Section has conducted numerous point source assessment surveys around Windsor industries as well as responding to allegations of soil contamination or vegetation injury by Windsor residents. Also, urban background contaminant surveys have been conducted. The contaminants of interest have been the trace metals as well as elements such as sulphur, sodium, chlorine and fluorine. Only recently have any samples destined for trace organic contaminant analyses been collected. At present there are insufficient data to permit an assessment of organic contaminant concentrations in biological and pedological matrices.

Soil and vegetation data generated by investigations and surveys in Windsor were amalgamated and assessed in a Phytotoxicology Section report (Pearson, 1989). This report drew on the chemistry of vegetation and soil collected in Windsor during the period 1972 to 1986. Windsor was divided into cells, based on street map coordinates and sampling locations assigned to the cells.

For the purposes of this review, the data appended to this report were reorganized and assigned into three categories depending on the location of the sampling site. These categories are designated as Windsor Urban, Windsor Industrial and Windsor Downtown. Figure 23 consists of an outline map of Windsor with the cells identified. The designations of the individual cells are indicated. The reader should be advised that industrial areas in Windsor are not restricted to any one location. However, there is a concentration of industries in west Windsor. This area is also directly across the Detroit River from the heavily industrialized Zug Island in Michigan.

Inorganic contaminant concentrations for samples of maple foliage and soil collected from the top five centimetres were extracted from the report. The locations of each sample were assigned to one of the three land use categories. Mean concentrations of the elements in maple foliage and soil for each category were calculated.

5.2 Metropolitan Toronto

In 1971 and 1981 the Phytotoxicology Section conducted Metropolitan Toronto wide surveys of contaminants in soil and vegetation. This survey concentrated on the effects of vehicular traffic on roadside lead contamination of soil. Maple foliage as well as foliage of other plants were also collected. Samples were analyzed for various element concentrations.

Because this survey was targeting effects of vehicular emissions on roadside soil, soil samples were collected at fixed distances of 25 and 75 feet from roadways. Samples were also collected at two depths, the top one inch and the four to six inch depth increment.

The results of these surveys have not been previously reported. The 1981 maple foliage and top one inch, 75 feet from the road, soil data were selected for examination in this review. The sampling locations in Metropolitan Toronto were separated into the downtown area and all other locations. Mean concentrations of the inorganic contaminants in maple foliage and the soil were calculated for these two areas. Figure 24 shows the sampling locations and the arc that separates the Toronto Downtown and Toronto Urban areas.

5.3 A Comparison of Contaminants in Windsor and Metropolitan Toronto

Gráphical comparisons of contaminant concentrations in maple foliage and soil from the three Windsor and two Toronto location categories are contained in Figures 25 through 37. Sufficient data were available for lead, chromium, copper, nickel, cadmium, arsenic, selenium, vanadium, iron, zinc and sulphur from all five areas and for both foliar and soil samples. Chlorine and fluorine data were only available for foliar samples from all five areas.

It should be stressed that the soil samples collected in the two cities were collected at two different depths. Those in Toronto came from the top one inch (2.5 cm). Recall that this survey was to assess vehicular emissions on roadside soil. Those selected from the Windsor surveys were collected to a depth of five centimetres, which is the standard sampling depth now employed by the Phytotoxicology Section. There were insufficient top 2.5 cm samples collected in Windsor to be useful.

Due to differences in the purposes of sampling in the two urban environments, any comparisons of contaminant concentrations must be viewed with caution. This is especially the case for the soil data. If it is assumed that contamination of soil is the result of atmospheric deposition, a concentration gradient will develop in the soil profile. A shallower sample will have higher concentrations, assuming other variables are held constant. Due to the differences in soil sampling depth between the cities, samples from Toronto locations will be biased toward higher contaminant concentrations.

FIGURE 23

Cell Designations for Windsor Maple Foliage and Soil Sampling Locations

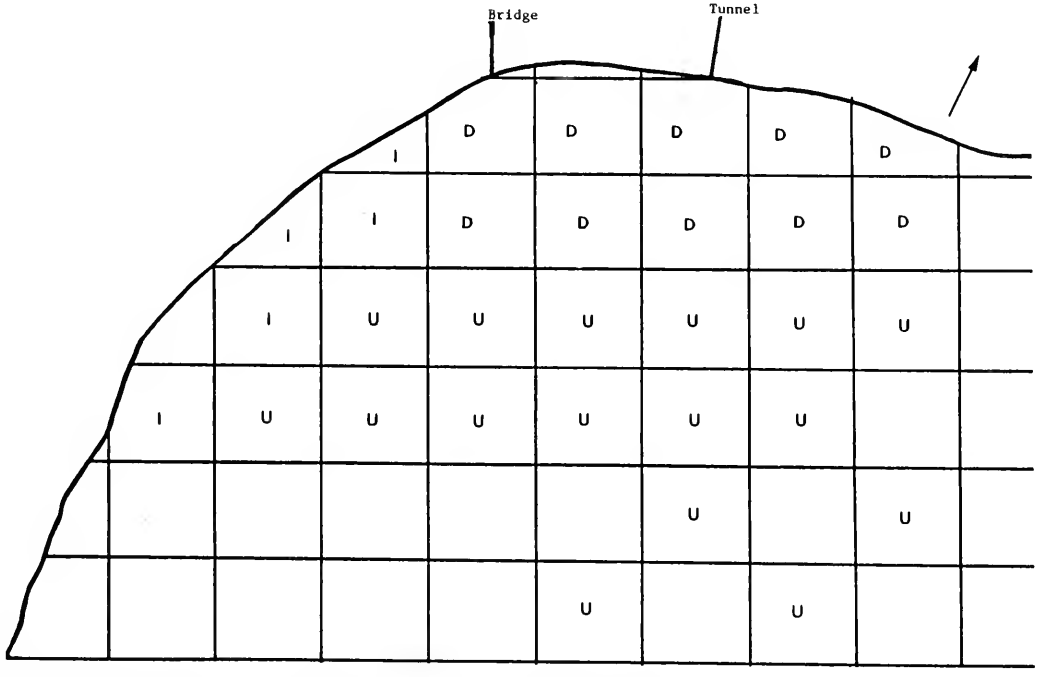
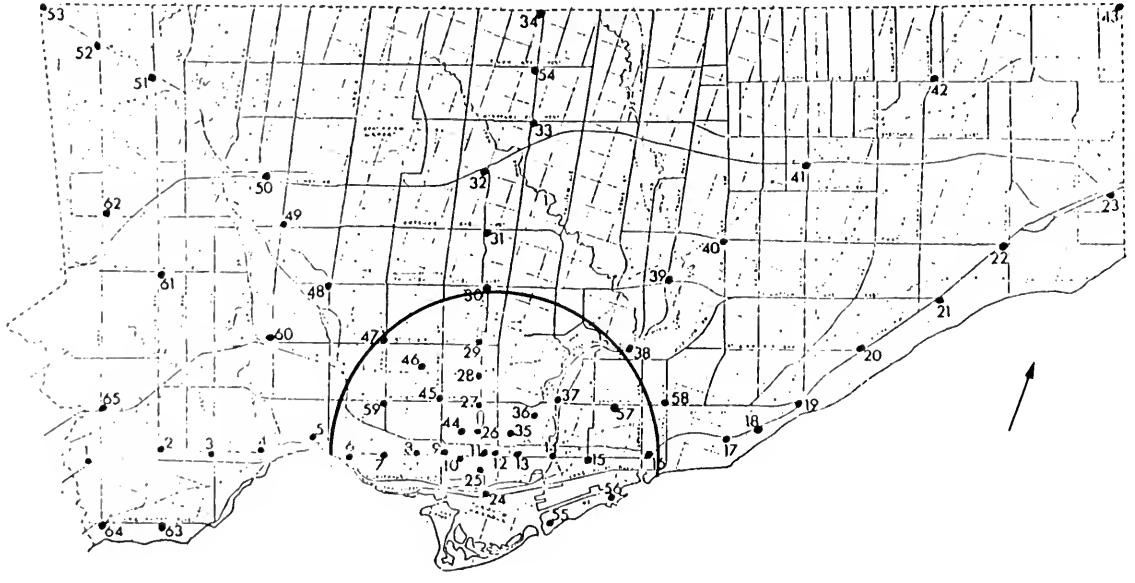


FIGURE 24

Metropolitan Toronto Maple Foliage and Soil Sampling Locations



Note: The arc separates "Downtown" and "Urban" sampling locations.

In addition, the differences in objectives for sample collection between the two cities may produce bias in the data. The collections in Windsor were for the purpose of monitoring industrial sources as well as background surveys. The Toronto survey restricted sampling to vehicular arteries. Depending on the contaminant under scrutiny, higher or lower degrees of contamination may due to the sampling design, or may truly reflect differences in the two urban environments.

To test the significance of any differences between the five area categories with respect of inorganic contaminants, an analysis of variance was performed using Duncan's Multiple Range test. The figures contain alphabetic characters above each histogram. Significant differences between element concentrations in the different areas are represented by different characters. The character "a" above a histogram indicates an area or areas with the highest concentrations of the element.

A detailed interpretation of this information is not appropriate. As mentioned above, the data were derived from investigations with diverse purposes. Also, there is the inconsistency of soil sampling depths between the two cities. Never-the-less, there is a notable tendency for higher contaminant concentrations in maple foliage collected in the Windsor Industrial area. Of the 13 foliar element concentrations available, seven were significantly higher than any of the other four areas. These include Ni, Cd, As, Se, V, Fe and F. Two other elements, Cr and Zn fell into the highest concentration group with one or more of the other two Windsor areas. Five of the 13 elements had higher concentrations in all Windsor areas than in any Toronto area. These include Cr, Ni, Cd, Fe and Zn.

The only element that had the highest concentration in Toronto maple foliage was chlorine. This is not unexpected since the samples were collected near major roads and probably reflects the use of deicing salt. Only lead and copper in Toronto fell into the high concentration group. Even so they were accompanied by the Windsor Industrial and Windsor Downtown areas, respectively, in these groups.

The soil data also reflect some distinctive trends. It must be emphasized that soil samples collected in Toronto were collected from the top 2.5 centimeters, and therefore should be biased toward higher contaminant concentrations if atmospheric deposition is the source. Despite this bias, Windsor soil samples, from all three areas, had the highest concentrations of Ni and Cd, falling into their own statistical group. The concentration means of these elements were highest in the Windsor Industrial area. Se and Fe from the Windsor Downtown and Industrial areas were significantly higher than all other ares.

The only element that stood out as being the highest in Toronto was Pb in the Downtown area. This is highly indicative of high traffic volumes and vehicle exhaust as the source.

Despite any cautions that have been expressed prior to drawing comparisons between the two cities, there stand out certain trends which cannot be dismissed. The extent of contamination of vegetation and soil by certain elements appears more pronounced in Windsor. This is especially the case for the Windsor Industrial Area. While it may be argued that this contamination is a result of local, Windsor-based, industries or sources, it should be noted that the contaminants in question are not associated with the type of industries located in the Windsor Industrial area. They are associated with ferrous and non-ferrous smelting and refining operations; such as those located on Zug Island in Michigan.

FIGURE 25 a

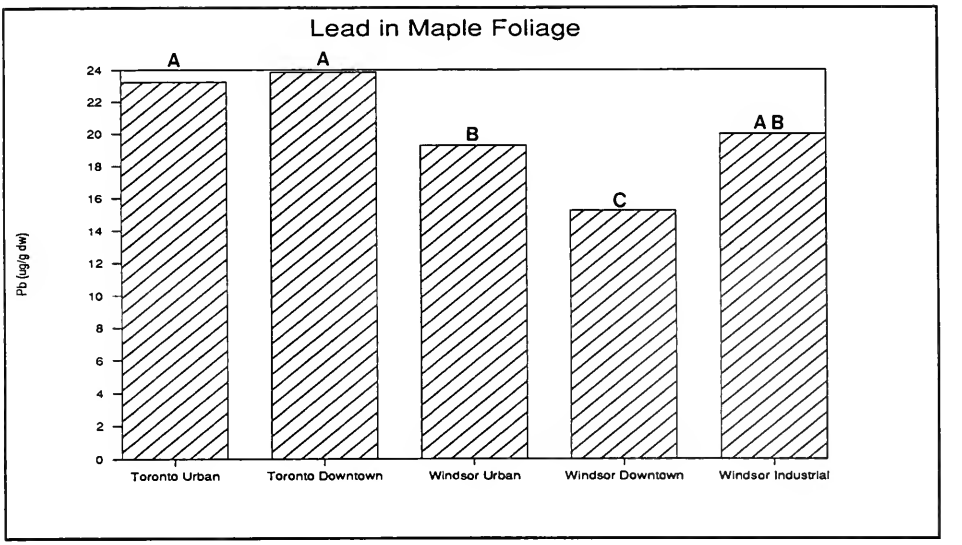


FIGURE 25 b

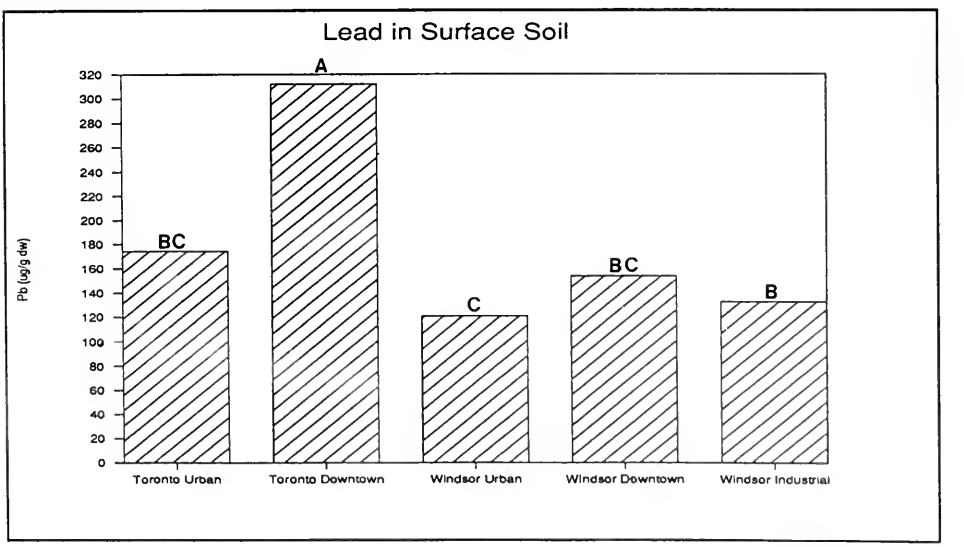


FIGURE 26 a

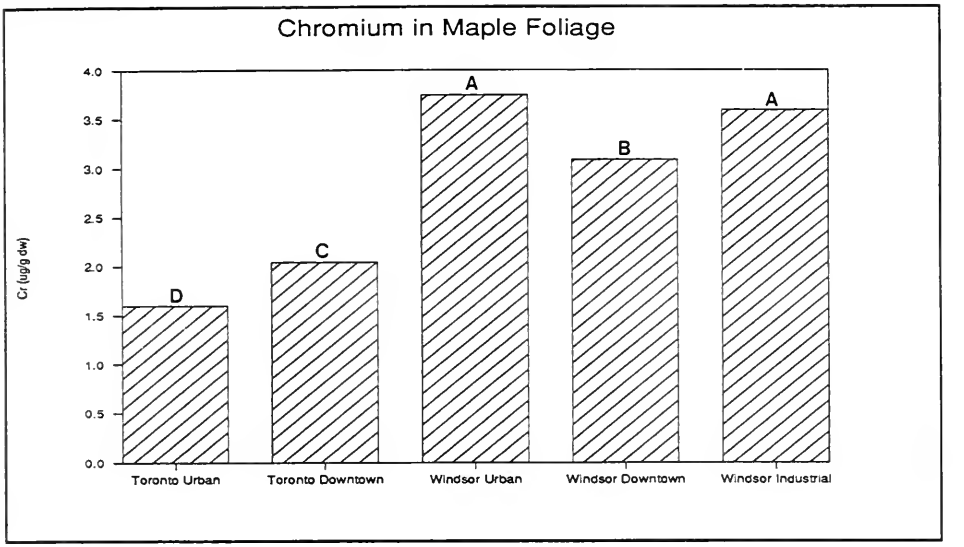
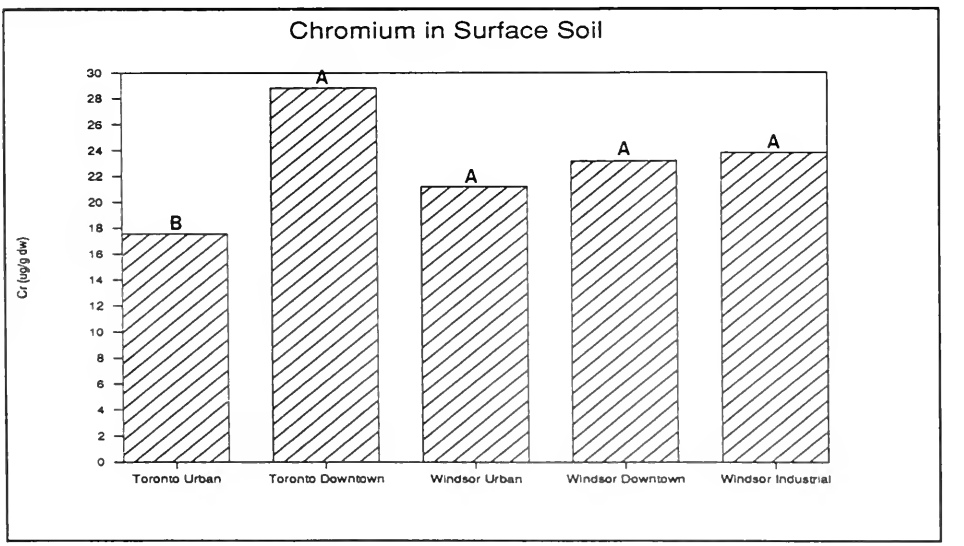


FIGURE 26 b



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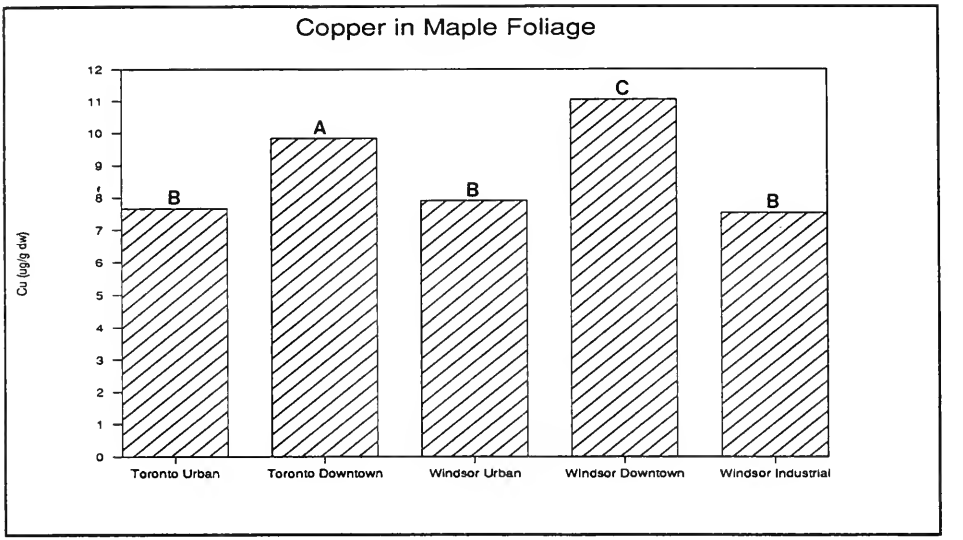

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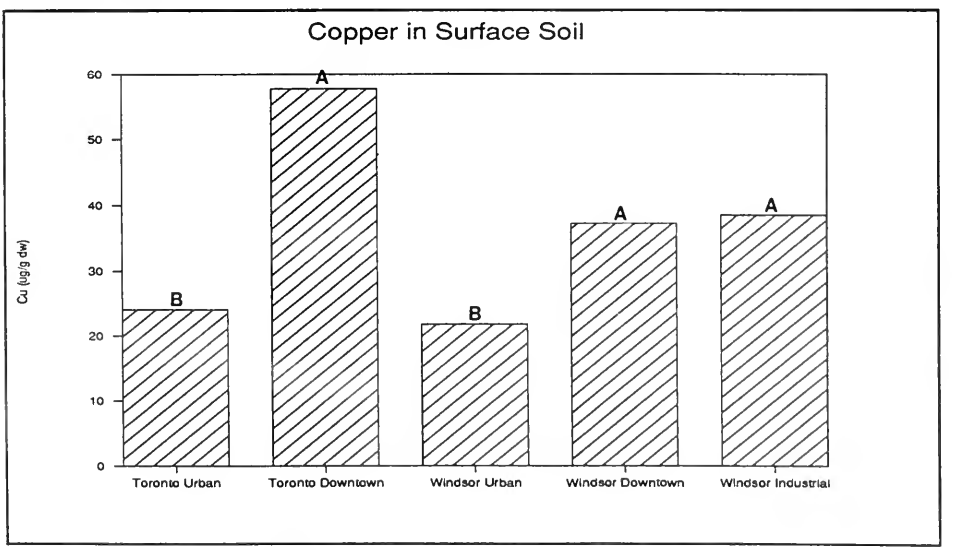

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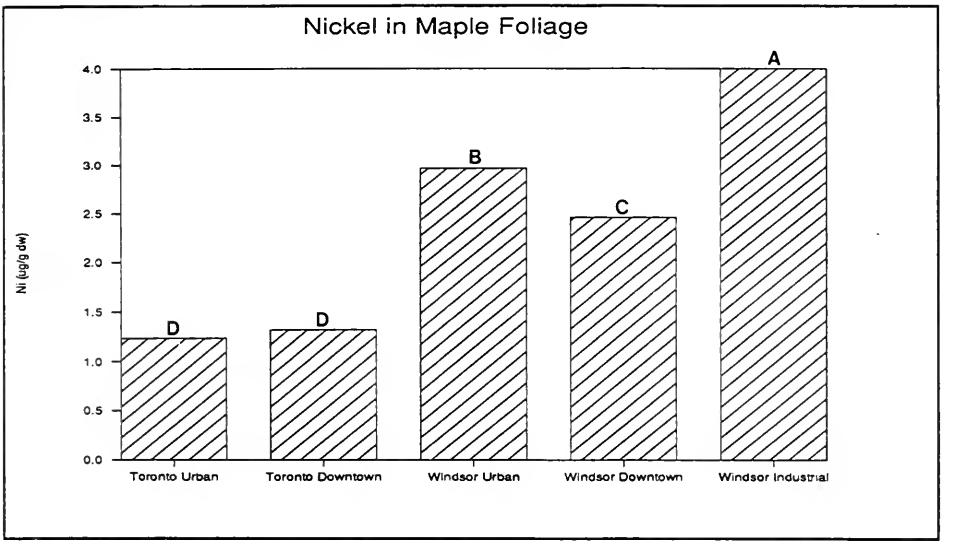

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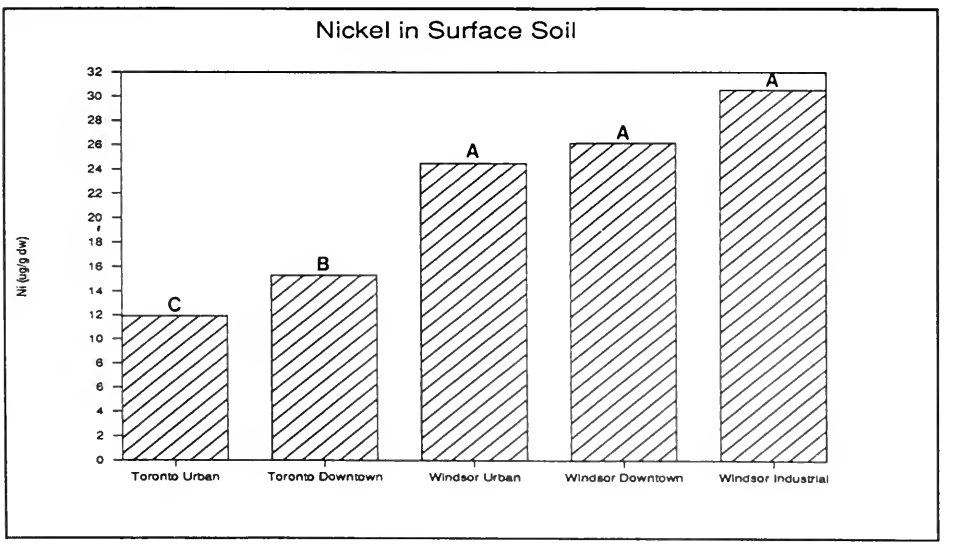

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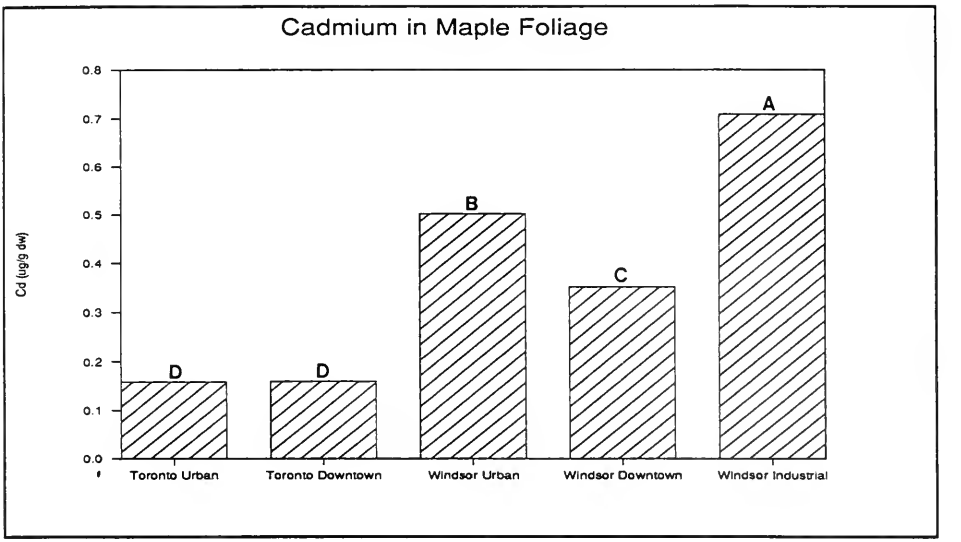

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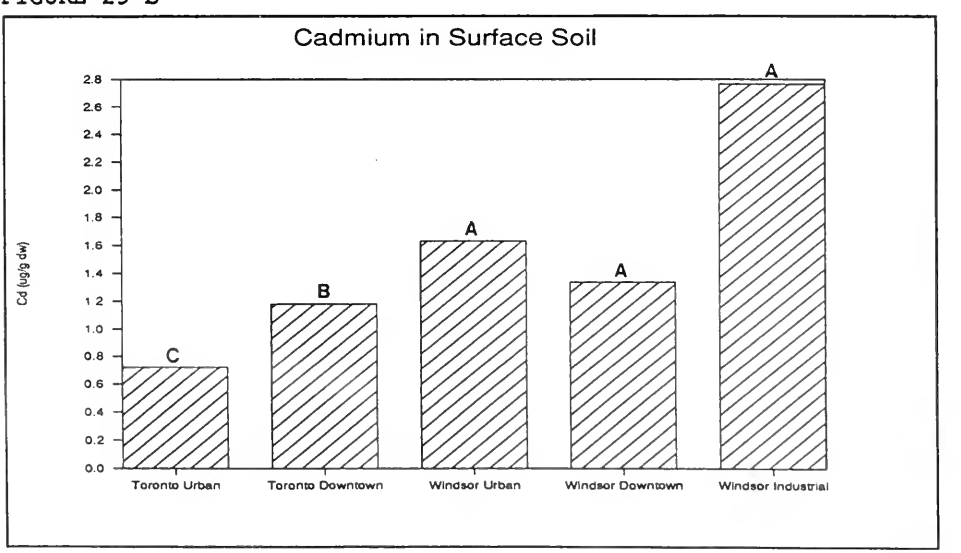

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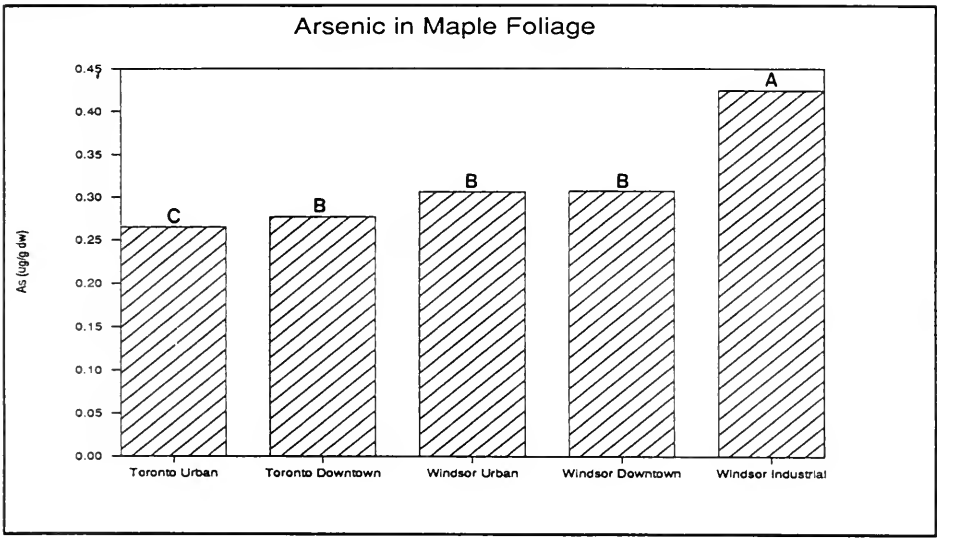

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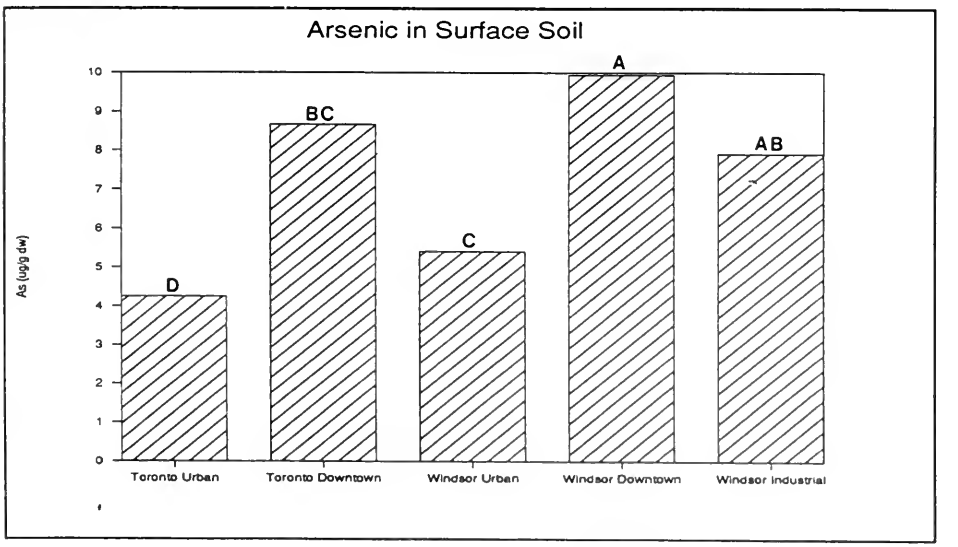

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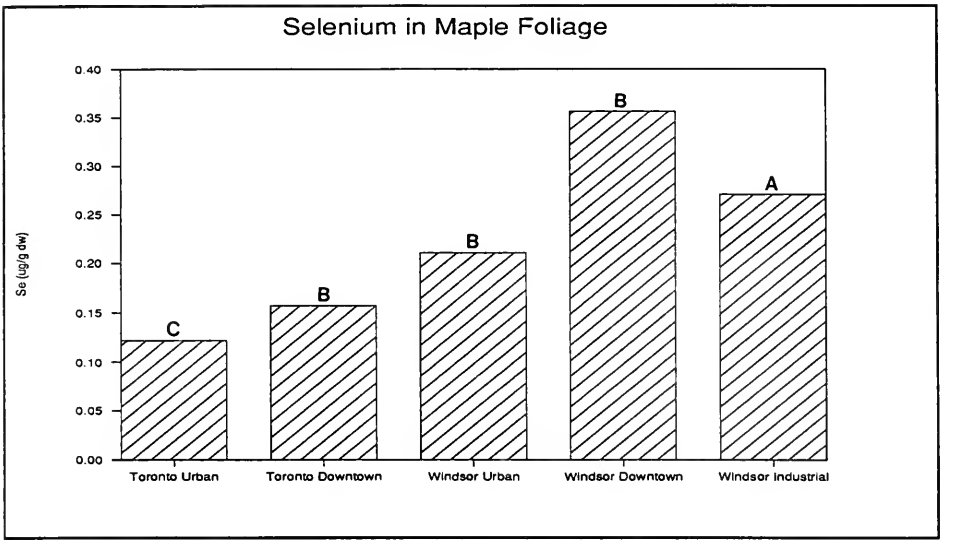

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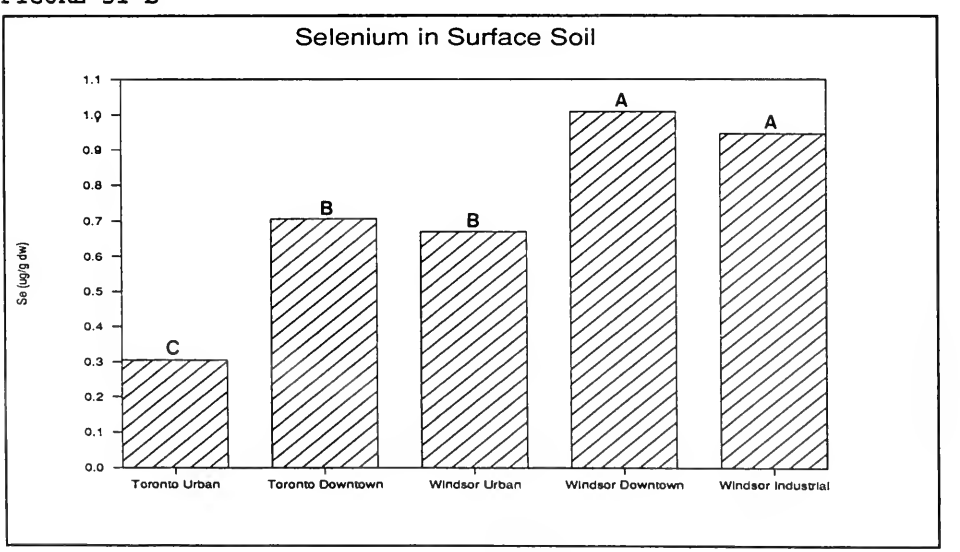

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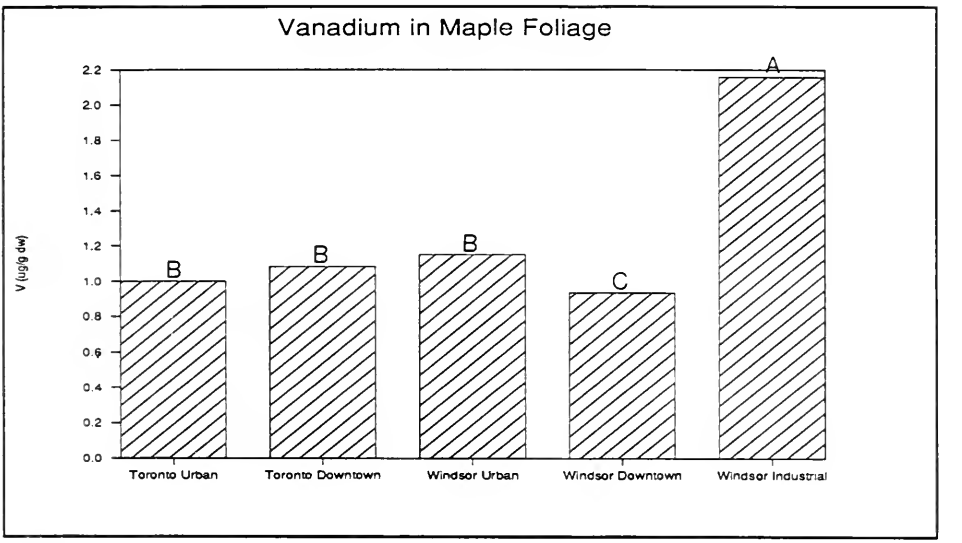

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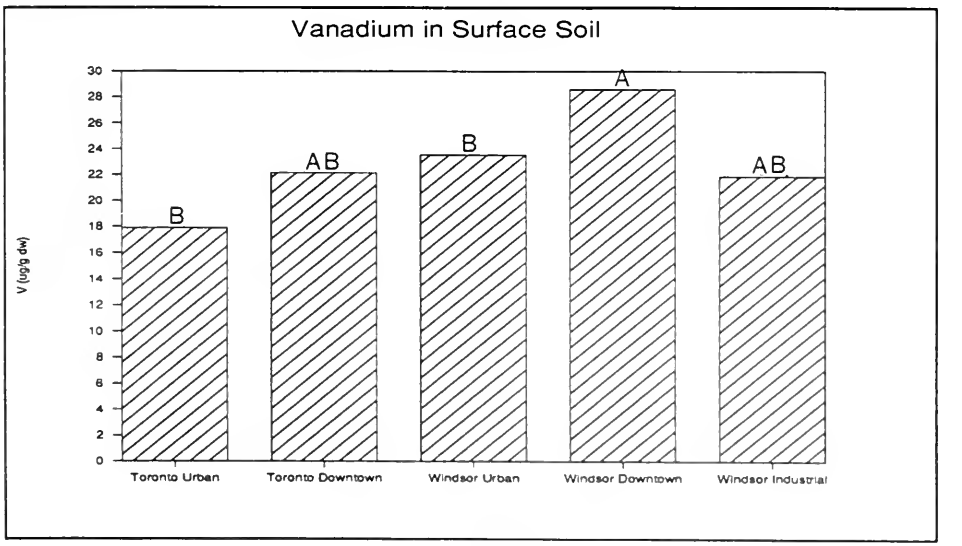

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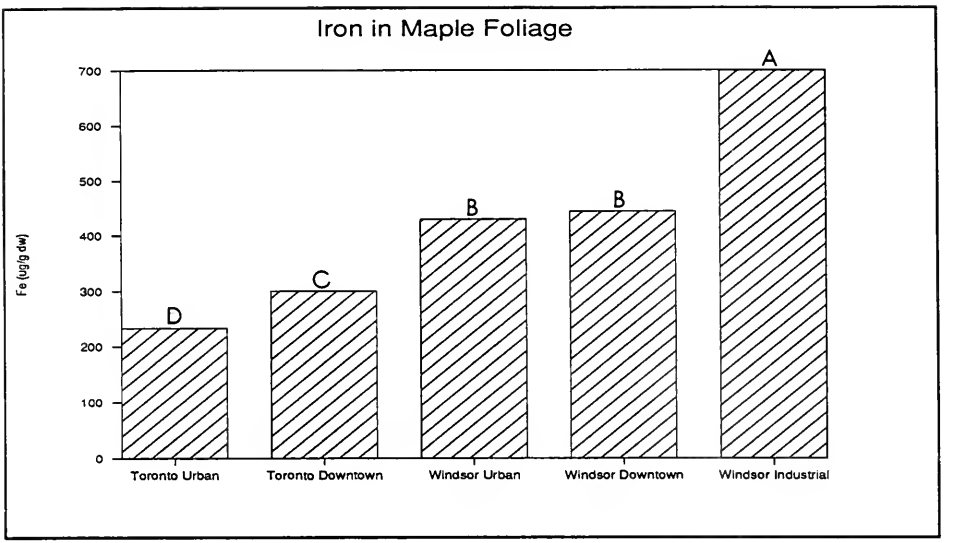

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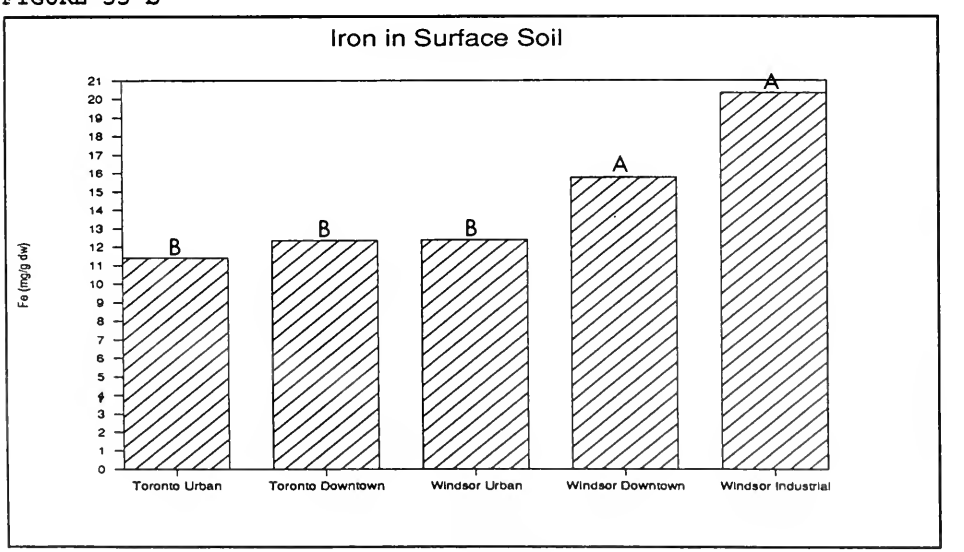

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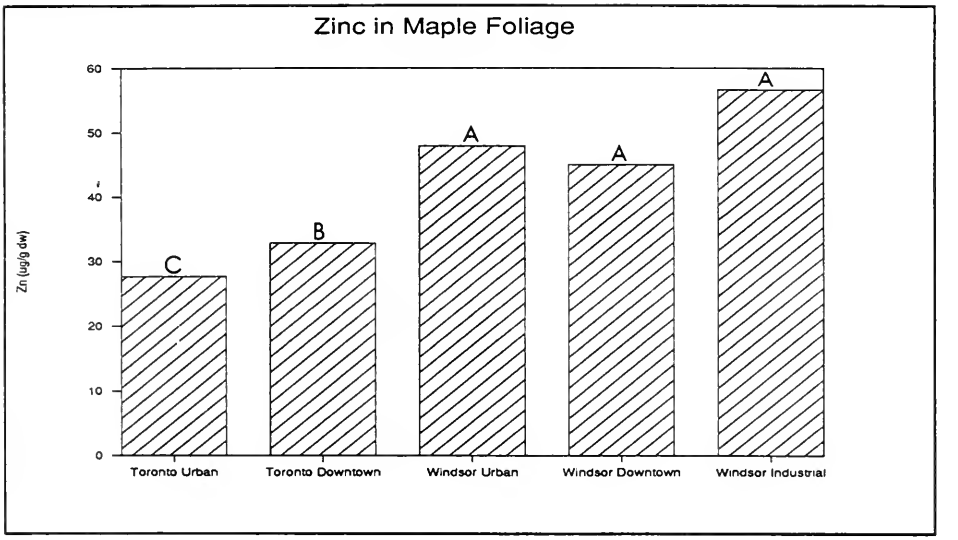
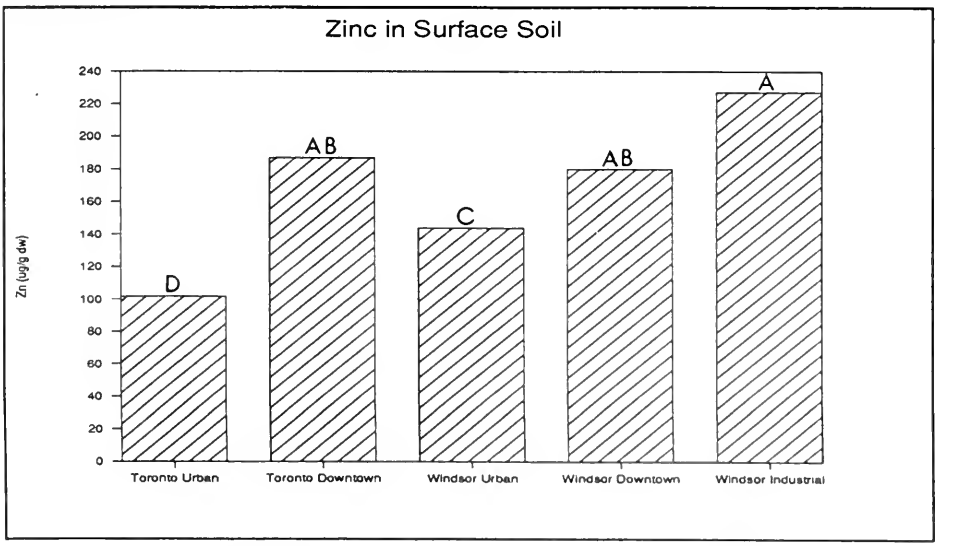


FIGURE 34 b



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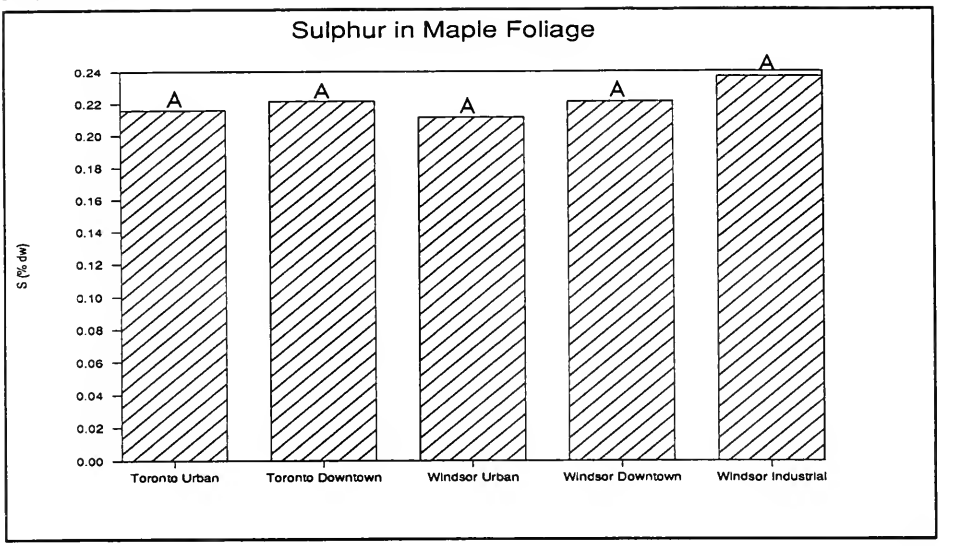

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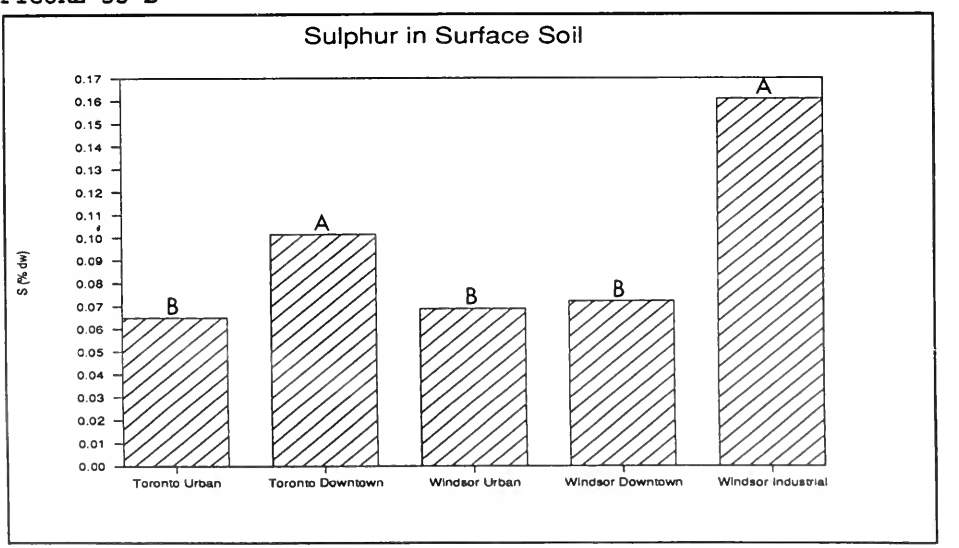

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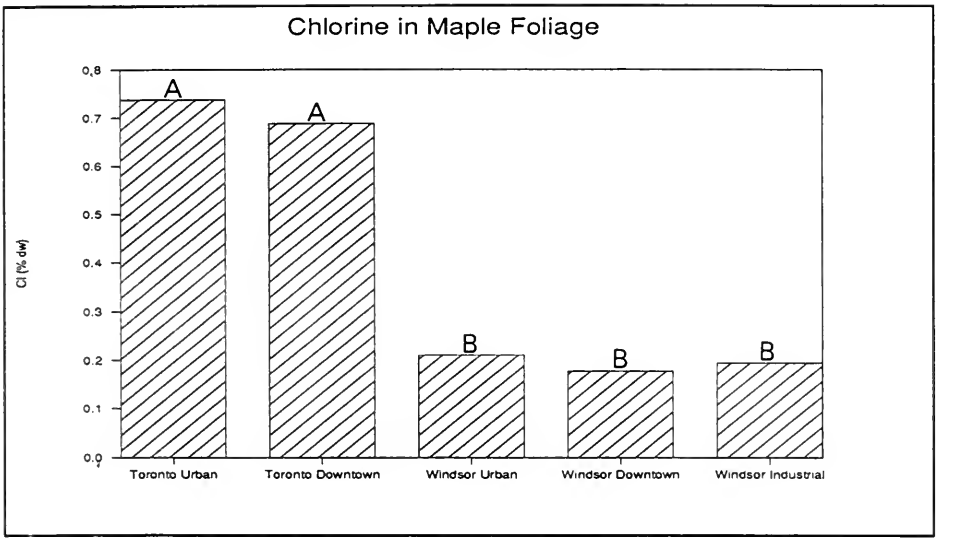
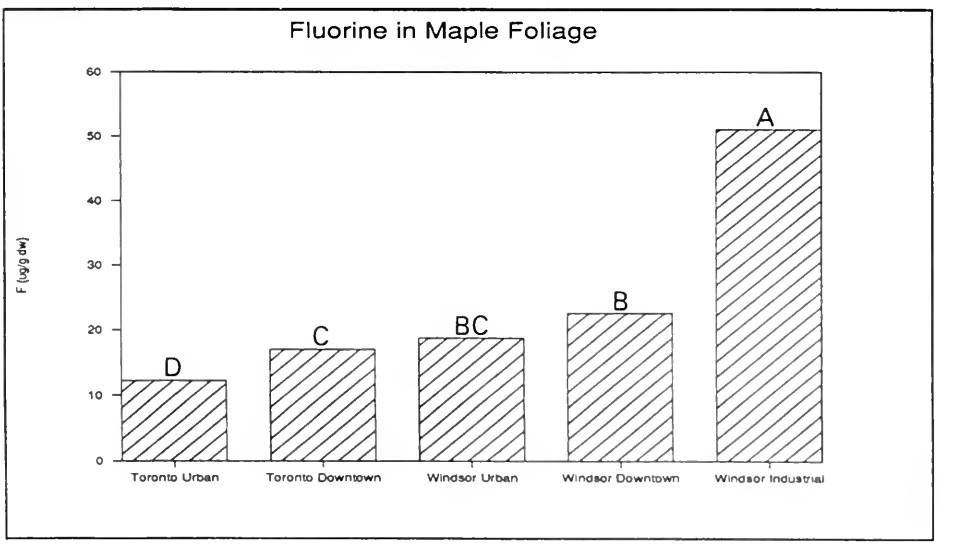


FIGURE 37



6 CONCLUSIONS AND RECOMMENDATIONS

A preliminary analysis was carried out on the air quality, and other relevant data (emissions and soil and vegetation contamination) in the Corridor.

An examination of the emissions inventory for various toxic chemicals reveals that, while emissions are elevated in southwestern Ontario relative to the rest of the province due to the concentration of population and industry, on a continental scale this is not a major source area. It should be noted, however, that an area centred on Detroit, Michigan is a major source area for toxics emissions. The ambient air quality data suggest that the influence of this major US emissions area is felt on the Canadian side of the border, at Windsor.

If 25 Ontario cities, where the provincial Air Quality Index is measured, are ranked by population and 1988 level of air contaminants, it is found that while Windsor ranks ninth and Sarnia 24 th in population, they had the following rankings in annual average (summer average for O_3) air pollution levels:

Contaminant	Windsor Rank	Sarnia Rank	Cities with data
O_3	2	10	25
SO_2	2	3	25
TSP	2	12	18
Pb	4	9	17
Cr	2	5	8

The database for volatile and semi-volatile organic contaminants in air is much less extensive than that for the "classic" pollutants mentioned above. An analysis was carried out on ambient levels in the Windsor area for some representative compounds, namely PAH, Dioxins/Furans, benzene, dichloromethane and trichloroethylene. The results suggest that, with the exception of B(a)P, average concentrations of these compounds in the Windsor area are not markedly different from levels reported for other similar size North American cities. On the other hand, the average B(a)P concentration is comparable to levels in the much larger cities of Montreal and Los Angeles, and double the levels found in Toronto and Vancouver. It is interesting to note here that an analysis of some of the available TRS compound data clearly shows the effect of Zug Island, a heavily industrialized area on the US side of the border, on air quality at West Windsor. The coke ovens at Zug Island emit TRS-type compounds as well as PAH and other toxic organics. Also, stratifying the organics data by concentration level shows that for B(a)P and PCDD/PCDF higher concentrations occur with air flows from the Detroit area.

An evaluation has also been carried out on soil and vegetation contamination in the Windsor area and compared to similar data from Metropolitan Toronto. While caution must be exercised in comparing the data from the two cities, the extent of contamination by certain elements appears to be more pronounced in Windsor, especially in the Windsor Industrial area (West Windsor), suggesting a long-term anthropogenic impact from industries not located there, but rather smelting and refining operations such as those on Zug Island.

The above results are from a preliminary analysis. Clearly, more work is necessary, not only in analyzing the available database, but also in expanding the information base on airborne toxics and the emissions information for the pfCorridor, particularly for the toxic organics and trace metals.

Given the findings of this report, it is recommended that comprehensive multi-year environmental and human health assessment studies be undertaken in the Huron-Erie Corridor.

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8 ACKNOWLEDGMENTS

The authors wish to express their gratitude to Phil Kiley, Duncan Frazer, Simon Wong and Bob Chai of the Air Resources Branch for their support in the compilation and analysis of data for this report. Mr. Glenn Grosse of the Southwestern Region provided valuable commentary on the draft of this report.